



OSRAM
SYLVANIA

RCRA Facility Investigation Final Report

OSRAM Sylvania Products, Inc.
Wellsboro, Pennsylvania

Volume 1

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Table of Contents

VOLUME 1

EXECUTIVE SUMMARY	E.1
1. INTRODUCTION	1.1
1.1 Purpose	1.1
1.2 Site Background	1.1
1.2.1 Facility Description	1.1
1.2.2 Release History	1.3
1.3 Objectives	1.4
1.4 Report Organization	1.7
2. FIELD INVESTIGATION ACTIVITIES	2.1
2.1 Community Relations Meetings	2.1
2.2 Monitoring Well and Piezometer Installation	2.2
2.3 Continuous Level Recorders, Stream Gauges and Rain Gauge	2.6
2.4 Borehole Geophysical Investigation	2.9
2.5 Well Sampling and Water Level Measurements	2.10
2.6 Human Receptor Characterization	2.13
2.7 Ecological Assessment	2.15
2.8 Aquifer Testing and Analysis	2.17
2.8.1 Preliminary Slug Tests	2.17
2.8.2 Pump Tests	2.18
2.8.3 Groundwater Gradients	2.21
3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA	3.1
3.1 Surface Features	3.1
3.2 Geology/Soils	3.2
3.2.1 Regional Geology	3.2
3.2.2 Site Geology	3.4
3.3 Hydrogeology	3.5
3.3.1 Regional Hydrogeology	3.5

Table of Contents

(Continued)

3.3.2	Site Hydrogeology	3.6
3.4	Surface Water Hydrology	3.9
3.5	Climate and Meteorology	3.10
3.6	Lane Use and Demography	3.10
3.7	Potential Receptors, Habitats and Exposure Pathways	3.12
4.	NATURE AND EXTENT OF CONTAMINATION	4.1
4.1	Potentially Elevated Parameters	4.1
4.2	Occurrence and Distribution and Groundwater Contaminants	4.3
4.3	Statistical Analysis	4.5
5.	CONTAMINANT FATE AND TRANSPORT	5.1
5.1	Bedrock Groundwater Flow Model	5.2
5.2	Fate and Transport	5.3
5.2.1	Hexavalent Chromium	5.4
5.2.2	Arsenic	5.7
6.	HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT	6.1
6.1	Screening-Level Problem Formulation	6.2
6.1.1	Environmental Setting	6.2
6.1.2	Known and Suspected Contaminants	6.2
6.1.3	Contaminant Fate and Transport	6.3
6.1.3.1	Arsenic	6.3
6.1.3.2	Chromium	6.4
6.1.4	Toxicity	6.6
6.1.4.1	Arsenic	6.6
6.1.4.2	Chromium	6.6
6.1.5	Potentially Complete Exposure Pathways and Receptors	6.8
6.1.6	Screening-Level Ecological Effects Evaluation	6.9

Table of Contents

(Continued)

6.2	Screening-Level Exposure Assessment	6.11
6.2.1	Exposure Parameters and Concentrations	6.11
6.2.2	Screening-Level Evaluation	6.12
6.3	Uncertainty in Screening-Level Evaluations	6.13
7.	SUMMARY AND CONCLUSIONS	7.1

REFERENCES

TABLES

Table 1 -	RFI Groundwater Elevations
Table 2 -	Calculated Vertical Gradients
Table 3A -	Trigger Level Determination
Table 4A -	RFI Sampling Results - Round 1
Table 4B -	RFI Sampling Results - Round 2
Table 4C -	RFI Sampling Results - Round 3
Table 4D -	RFI Sampling Results - Round 4
Table 4E -	RFI Sampling Results - Summary
Table 5 -	Historical Hexavalent Chromium Concentrations
Table 6 -	Statistical Analysis Summary

FIGURES

Figure 1 -	Location Map
Figure 2 -	Site Plan
Figure 3A -	Shallow Aquifer Potentiometric Surface Map - October 1998
Figure 3B -	Shallow Aquifer Potentiometric Surface Map - February 1999
Figure 3C -	Shallow Aquifer Potentiometric Surface Map - May 1999
Figure 3D -	Shallow Aquifer Potentiometric Surface Map - August 1999
Figure 4A -	Isoconcentration Map, Dissolved Hexavalent Chromium - October 1998

Table of Contents

(Continued)

Figure 4B - Isoconcentration Map, Dissolved Hexavalent Chromium -February 1999

Figure 4C - Isoconcentration Map, Dissolved Hexavalent Chromium - May 1999

Figure 4D - Isoconcentration Map, Dissolved Hexavalent Chromium - August 1999

Figure 5 - Geologic Cross Section A-A

Figure 6 - Geologic Cross Section B-B

Figure 7 - Water Supply Wells

VOLUME 2

APPENDICES

Appendix A - Grain Size Analyses

Appendix B - Boring Logs

Appendix C - Well and Piezometer Construction Diagrams

Appendix D - Borehole Geophysics Report and Logs

Appendix E - Aquifer Test Data and Calculations

Appendix F - Ecological Assessment Information and Data

Appendix G - Continuous Water Level Monitoring Data

Appendix H - Fate and Transport Data and Calculations

Appendix I - Charleston Creek Flow Data

Appendix J - Laboratory Data Sheets and Chain-of-Custody Forms



EXECUTIVE SUMMARY

OSRAM SYLVANIA Products Inc. (OSRAM) has completed the RCRA Facility Investigation (RFI) at its Wellsboro, Pennsylvania facility in accordance with the EPA-approved RFI Workplan. This investigation included installing new groundwater monitoring wells and piezometers, installing continuous level recorders and stream gauges, surveying, performing a borehole geophysical investigation, collecting and analyzing groundwater samples, researching nearby private water supply wells, conducting an ecological assessment, conducting aquifer tests, performing fate and transport calculations, and performing a risk assessment. These activities have led to the following findings and conclusions:

1. The groundwater monitoring network at the site is adequate to address the RFI objectives.
2. The concentrations of dissolved hexavalent chromium in groundwater are stable and consistent with previous data and indicate that hexavalent chromium has not migrated offsite.
3. Dissolved arsenic was the only parameter from the Abbreviated Appendix VIII list that was identified at a concentration in excess of the Trigger Level. This occurred at only one well (MW-13).
4. Contaminated groundwater migration is controlled at the facility.
5. Human health and ecological exposure is controlled at the facility.
6. The facility has completed its obligations under the RCRA Corrective Action program.



1. INTRODUCTION

1.1 Purpose

This RCRA Facility Investigation Report presents the data and findings from the investigative efforts performed during the RCRA Facility Investigation (RFI) at the OSRAM SYLVANIA Products Inc. (OSRAM) facility in Wellsboro, Pennsylvania. The RFI was performed in accordance with the Final Administrative Order on Consent, RCRA Number 3-072-CA, and the RFI Workplan that was approved by the United States Environmental Protection Agency (EPA) on July 21, 1998.

An Interim Summary Report was prepared and submitted in February 1999 in accordance with Section 3.2.8 of the RFI Workplan. In order for this RCRA Facility Investigation Report to serve as a "stand-alone" document, it includes much of the information that was presented in the Interim Summary Report, along with the information that was obtained subsequent to the submission of the Interim Summary Report.

1.2 Site Background

1.2.1 Facility Description

The OSRAM facility is located at the intersection of Austin and Jackson Streets in the Borough of Wellsboro, Pennsylvania. The facility can be found on the United States Geological Survey (USGS) Antrim, Pennsylvania quadrangle map at coordinates 41° 44' 56.4" latitude and 77° 17'



16.5" longitude. Refer to Figure 1 for a site location map.

The facility occupies approximately 20 acres of property. The property boundary and general plant layout are shown in Figure 2.

The OSRAM facility primarily produces lime glass envelopes (the glass portion of incandescent light bulbs), which are sent to other plants for final assembly. The current manufacturing process includes the following major operations:

- The formation of molten glass from raw materials inside a central furnace. Raw materials used in the glass making operation include limestone, silica sand, soda ash, salt cake, nepheline syenite, coal fines and cullet (reground glass ribbon). Bulk raw materials (except cullet) are delivered by truck and rail and stored in storage silos located on the property. The glass furnace is heated with natural gas with a standby propane reserve fuel source.
- The introduction of a thin stream of molten glass (ribbon) into ribbon machines where a proprietary automated conveyer process utilizes blown air and cast iron molds to form bulbs from the molten ribbon.
- A frosting operation where an acidic solution is used to etch the bulb interiors.
- A bulb coating operation where various ceramic and other finishes are applied.
- Assorted automated and manual handling, packaging and shipping functions.
- A small chrome plating operation to replate worn blowheads used on the ribbon machines
- Assorted maintenance and administrative activities.



The facility is believed to have been constructed in 1886 by the Columbia Glass Company. It is believed that the facility was purchased by the Corning Glass Works in 1916. Corning Glass Works sold the facility to GTE Products Corporation, a Delaware corporation, pursuant to a Purchase and Sale Agreement dated August 7, 1981. To reflect a change in its ownership, GTE Products Corporation changed its name to OSRAM SYLVANIA Inc. on February 1, 1993. Internal restructuring that occurred on April 1, 1997 resulted in the facility name being changed to the current OSRAM SYLVANIA Products, Inc.

1.2.2 Release History

Located immediately adjacent to the southern wall of the Former Furnace Building and outside of the plating room was a former shallow dry well. Reportedly, chromium plating rinse water was routinely discharged to the dry well by Corning, a former owner and operator of the facility. Exact dates during which the dry well was used by Corning are not known, but this practice ceased before 1980. The former dry well was discovered by OSRAM in 1987 when responding to a minor spill (approximately 5 gallons) of chromium rinse water outside the plating room. In 1989, the facility removed approximately 85 cubic yards of chromium-impacted soil surrounding the dry well under the oversight of the Pennsylvania Department of Environmental Resources. Groundwater monitoring performed prior to and after the removal action confirmed that chromium constituents had reached the shallow groundwater aquifer and had migrated to the northwest and away from the immediate former dry well area. The distribution of chromium concentrations in the monitoring well network that had been installed supports the identification of the former dry well as the primary release point, and indicated that the downgradient extent of chromium migration appeared to be within the facility boundary.



1.3 Objectives

The RFI Objectives that were defined in the approved RFI Workplan include the following tasks:

1. Install 4 (3 downgradient, 1 upgradient) new shallow monitoring wells at the site for groundwater quality sampling. Downgradient wells were to be located near the northwest property boundary.
2. Install 4 new deep piezometers (bottom of unconsolidated zone), paired with selected shallow wells, for hydraulic gradient determination.
3. Perform a long-term pump test (approximately 48 hour duration) on a new or existing well to define aquifer characteristics. This pump test was conditional upon obtaining PaDEP approval for temporary modification to the NPDES permit to allow discharge of the pump test water.
4. Install 4 stream level gauges in Charleston Creek and determine water elevations in Charleston Creek.
5. Install continuous water level recorders in two of the new shallow monitoring wells, two of the new deep piezometers, an existing production well and one of the stream gauges to evaluate short-term and seasonal fluctuations in groundwater gradients.



6. Identify potential downstream and downgradient receptors (e.g., public and private drinking water wells, including location and screened interval) and plot on site location map.
7. Perform abbreviated Appendix VIII analysis on the groundwater samples collected from the new wells. Perform dissolved trivalent and hexavalent chromium compound analysis on the other 10 existing site monitoring wells, including QA/QC analyses.
8. Plot shallow and deep potentiometric surface maps. Calculate vertical and horizontal flow gradients and evaluate Charleston Creek interconnections.
9. Tabulate groundwater monitoring results, and identify potentially elevated parameters by comparing downgradient results (e.g., from monitoring wells near northwest property boundary) to the higher of the following trigger levels:
 - Upgradient concentrations
 - Current Drinking Water Maximum Contaminant Levels (MCLs) or U.S. EPA Region III Risk Based Concentration Table, if no MCL exists for a given parameter.
10. Plot isoconcentration maps for potentially elevated parameters in groundwater.
11. For potentially elevated parameters in groundwater, model contaminant movement



to most critical receptors. Calculate contaminant concentration at receptors and perform risk analyses.

12. For any identified potentially elevated parameters, perform additional groundwater monitoring for three additional quarters. Information to be gathered during monitoring was as follows:
 - Water elevation – all site wells and piezometers and Charleston Creek
 - Parameters identified as potentially elevated in the new wells
 - Dissolved trivalent and hexavalent chromium compounds from approximately 5 existing wells (actual number was to be dependent on observed conditions)
 - Repeat items 8 through 11 for each quarter's data
13. After collection of 4 quarters of data for potentially elevated parameters, perform statistical evaluation on the compiled data set. Revise fate and transport models as needed.
14. Conduct an ecological assessment, including a study of aquatic species, wildlife, wetlands, and endangered species in the vicinity of the site.
15. Issue a report of findings, conclusions and recommendations.



1.4 Report Organization

This RCRA Facility Investigation report is organized as follows:

VOLUME 1

Executive Summary

This section presents a concise summary of the findings and conclusions of the RFI.

Section 1: Introduction

This section primarily discusses the background and purpose of the RFI.

Section 2: Field Investigative Activities

This section discusses the on-site investigative activities that were performed during the RFI.

Section 3: Physical Characteristics of the Study Area

This section discusses the surface and subsurface features of the site and its surrounding area.

Section 4: Nature and Extent of Contamination

This section discusses the results of the quarterly groundwater monitoring that was performed during the RFI, as well as various statistical and spatial distribution analyses that were performed on the data.



Section 5: Contaminant Fate and Transport

This section discusses the analyses that were performed to predict how on-site groundwater contaminants identified through the groundwater monitoring are expected to move through the environment over time.

Section 6: Human Health and Ecological Risk Assessment

This section discusses the identification of potential human and ecological receptors of on-site groundwater contaminants, the potential routes of exposure and the expected health risks associated with such exposures (if any).

Section 7: Summary and Conclusions

This section summarizes the conclusions that have been drawn as a result of the evaluation of the data and findings from the RFI.

Volume 1 also includes the tables and figures that were prepared to organize and present the RFI data and findings, and relevant references.

VOLUME 2

Volume 2 contains all of the supporting appendices to the RCRA Facility Investigation Report, as follows:

Appendix A contains the grain size analyses that were performed to select the proper filter pack materials for the new monitoring wells and piezometers.



Appendix B contains the boring logs that were prepared during the drilling activities associated with the installation of the new monitoring wells and piezometers.

Appendix C contains the diagrams illustrating how the new monitoring wells and piezometers were constructed.

Appendix D contains the logs and report of the borehole geophysical investigation that was performed on former Production Well 947.

Appendix E contains the data and calculations from the slug tests and pump tests that were performed during the RFI to evaluate aquifer characteristics.

Appendix F contains the information and data collected during the ecological assessment task of the RFI.

Appendix G contains the graphs of the continuous water level monitoring data and the rain gauge data that was collected during the entire RFI investigative period.

Appendix H contains the calculations from the contaminant fate and transport analyses.

Appendix I contains historical flow data for Charleston Creek, measured at the flume just east of the plant.



Section 1
Revision 0
April 14, 2000
Page 1.10

Appendix J contains copies of the laboratory data sheets and chain-of-custody forms from the quarterly monitoring that was performed.



2. FIELD INVESTIGATION ACTIVITIES

2.1 Community Relations Meetings

Prior to beginning field investigative activities, on-site informational meetings regarding the RFI were conducted with key community leaders. These meetings were conducted in accordance with Section 7 of the RFI Workplan.

The first Community Relations Meeting was conducted on August 28, 1998. Attendees at this meeting were as follows:

Mary Worthington - Director, Wellsboro Chamber of Commerce
Lynn Heck - President, Local 1001 of the American Flint Glassworkers Union
Robert DeCamp - Mayor of Wellsboro
Robert Blair - Director, Tioga County Development Corporation
Mark Dieffenbach - Wellsboro Superintendent of Public Works
David Cohick - Director, Tioga County Department of Emergency Services
Dan Brought - Supervisor, Wellsboro Water Treatment Systems
John Dugan - Wellsboro Council President

Representing OSRAM SYLVANIA Products, Inc. at the meeting were the following:

Robert Alspaugh - Wellsboro Plant Manager
Gerd-Otto Eckstein - Engineering Manager
Tom Lang - Senior Engineer and primary RFI contact
Dale Krysiniski, P.E. - Killam Associates RFI Project Manager

A second Community Relations Meeting was then conducted on September 21, 1998 for those key community leaders that were unable to attend the first meeting. This meeting followed the same format as the first, and was attended by the following community representatives:



Jack Robertson – Charleston Township Council President
Boyer Kantz – Charleston Township Municipal Chairman
Kyle Wheatly – Charleston Township Roadmaster

The meetings consisted of a presentation using overheads and was led by Robert Alspaugh. The presentation focused on explaining the RCRA Corrective Action process, the basis for the RFI, the activities that were to be performed during the investigation, the roles of various individuals and organizations and the implementation schedule. Following the presentation, the meeting was opened for discussion of any questions or concerns.

2.2 Monitoring Well and Piezometer Installation

Installation of the new monitoring wells and piezometers commenced on September 28, 1998. Well and piezometer locations are shown on Figure 2. The installation work was performed by Eichelbergers, Inc. of Mechanicsburg, Pennsylvania, under the supervision of Edward M. Davis, Field Geologist for Killam Associates. Prior to beginning drilling work, a site health and safety meeting was conducted by OSRAM to acquaint the drilling crew and Killam field personnel with health and safety requirements of the facility, as well as those described in Site Health and Safety Plan presented as Section 6.0 of the RFI Workplan. Other initial activities that were performed include setting up the decontamination area (which was a non-drained, concrete paved curbed area at the site) and staging drums at each drilling location for containerization of drill cuttings and development water.

All soil drilling was completed using 10-inch O.D., 6-1/4-inch I.D. hollow-stem augers. As augering proceeded, 24-inch long split spoon samples were collected at 5-foot centers, except in those instances where the field geologist determined that more frequent samples were needed to



adequately characterize the subsurface strata. In those instances where wells or piezometers were being installed adjacent to an existing well (as part of a cluster), the split spoon sampling was omitted in the horizon where such data had been collected during installation of the existing well. Split spoon samples were visually classified by the field geologist according to the USCS Classification Method and then placed in jars that were labeled to identify the drilling location and sample depth. The soil sample jars were then placed in boxes and retained on-site for possible future reference.

For shallow monitoring wells, drilling continued to a depth of about 5 to 9 feet beyond the depth where groundwater was first encountered. For the deep piezometers, drilling continued until bedrock was encountered (i.e., split spoon or auger refusal). During drilling, soil cuttings were containerized in 55-gallon drums, pending the results of the initial groundwater analysis for each location.

In several cases when drilling the boreholes for the deep piezometers, representative split spoon sampling of undisturbed formation material was not possible due to heaving of the formation material. Because of the confining hydraulic pressure of the aquifer, sand and gravel frequently filled the hollow stem of the augers when the pilot bit was removed for split spoon sampling. When this occurred, neither the split spoon nor the pilot bit could be returned to the sampling horizon.



Bedrock cores were obtained at P-2¹ and P-3 for the purposes of verifying the depth to bedrock and to allow an assessment to be made of the type and integrity of the bedrock. Coring was performed using an NQ-sized coring tool. Approximately 5 feet of rock core was obtained at each coring location. The cores were inspected by the field geologist for determination of rock type and Rock Quality Designation (RQD). The cores were then placed in standard core boxes and retained on site for possible future reference.

During the drilling of the first borehole (P-1), additional soil samples were collected from two horizons: 1) just below where groundwater was first encountered, and 2) near the bottom of the boring. These horizons represented the depths at which monitoring well or piezometer screens were to be installed. These soil samples were then subjected to grain size analyses in accordance with ASTM D-422². The results of these analyses, which are presented in Appendix A, were used to select the appropriate filter pack materials and well screen slot size. Soil samples collected from the two horizons appeared to be generally homogenous in particle size. Based on this testing, the filter pack selected consisted of #00N silica sand, and the selected screen slot size was 0.020 inches. Appendix A also includes information pertaining to the particle size distribution of the #00N sand.

Boring logs from this investigation are presented in Appendix B. After each boring was advanced

¹ P-2 was drilled adjacent to MW-12. Since bedrock was encountered at a depth of only 15 feet at this location (which is essentially identical to the depth of MW-12), a deep piezometer could not be installed at this location.

² The hydrometer portion of the analyses that would normally be performed on the soil particles passing the No. 200 sieve was omitted. This procedure is used to distinguish silts from clays, which is irrelevant to the selection of the proper filter pack and screen slot size.

to the target depth, installation of the monitoring well or piezometer was performed. Each well consisted of either 5 or 10 feet (depending on observed conditions) of 4-inch diameter, factory-slotted Schedule 40 PVC well screen with threaded connections and a bottom cap. Riser pipe above the screen consisted of 4-inch diameter Schedule 40 PVC with threaded connections. Filter pack sand was placed around the well screen to a depth of between 1 and 3 feet above the top of the screen. Above the filter pack a bentonite seal was placed using either bentonite pellets or chips, with each seal ranging in thickness from 1 to 10 feet, based on observed conditions³. The bentonite was hydrated with either formation water or, if installed above the water table surface, potable water. Above the bentonite seal, the riser was grouted in place using cement-bentonite grout to near the surface. Depending on the well or piezometer location, the installation was completed with either a flush-mounted cap or a steel protective casing with concrete collar.

Well and piezometer construction logs from this investigation are presented in Appendix C.

All downhole tools (e.g., augers, split spoons) were decontaminated via steam cleaning at the designated decontamination area between each drilling location.

After the new wells and piezometers were completed, they were developed to remove fine silty material and other drilling residuals. Development was performed by the driller using nitrogen air lift techniques or hand bailing. All existing on-site monitoring wells were also redeveloped in this manner since it had been several years since these wells were last purged or sampled.

³ Smaller bentonite seals were used in very shallow wells. Larger seals were used in deeper piezometers if the piezometer was adjacent to an existing shallow well to prevent possible grout contamination of the shallow well screened interval.



Development continued until the removed water was visibly clear. All development water was temporarily staged in drums on site and then later disposed of after the results of the initial groundwater analyses were obtained for each location.

Following the installation of new monitoring wells and piezometers and the designation of stream gauge benchmarks, all monitoring points (including the previously-existing monitoring wells) were surveyed for horizontal and vertical location. Surveying was performed by Boyer Kantz Surveying of Wellsboro, Pennsylvania. Well locations were determined using both State Plane Coordinates and latitude/longitude. This information is presented in a table on Figure 2. Elevations of the ground surface and the top of the PVC riser pipe (the reference point used for measuring depth to groundwater in each well) were determined at each well/piezometer. Water level reference elevations are presented in Table 1.

2.3 Continuous Level Recorders, Stream Gauges and Rain Gauge

To evaluate possible fluctuations in the groundwater horizontal and vertical gradients over time, continuous level recorders were established in key monitoring locations at the site. The level recorders (Global Water Model WL-14) feature a pressure transducer connected to a sealed microprocessor-based data logger. They were installed in an upgradient well cluster (MW-2 / P-1) and a downgradient cluster (MW-14 / P-4). The recorders were programmed to record and store a groundwater elevation once an hour by measuring the static head on the transducer. The system automatically compensates for changes in temperature and barometric pressure. During the course of the RFI, data from these recorders was periodically downloaded into a laptop computer using appropriate software, tabulated and graphed in paired time-series fashion. Graphs for the entire



12-month RFI period were prepared, along with a graph for each quarter (three-month period) within the RFI period.

The RFI Workplan also called for the installation of four stream gauges (SG-1, 2, 3 and 4) along Charleston Creek to assist in the evaluation of interconnections between the overburden aquifer and surface waters. SG-1 was installed on a concrete abutment that was part of the flow monitoring flume structure located east of the plant. This gauge consisted of a brass and wood surveying rod, 3.5 feet long and calibrated in tenths of a foot. Rather than install permanent staff gauges at SG-2, 3, and 4, a benchmark was established at each location, from which measurements could be taken down to the stream surface. This approach was judged to be more reliable and less prone to accidental damage or vandalism than staff gauges. A staff gauge was still used at SG-1 since the only available suitable benchmark (the top of the concrete abutment) has in the past been submerged during periods of very high flow. The benchmark for SG-2 was established at a point on the handrail on the steps leading to Outfall 001. The benchmark for SG-3 was established at a point on the eastern edge of the bridge carrying Jackson Street across Charleston Creek. The benchmark for SG-4 was established at a point on the western girder of a railroad bridge crossing Charleston Creek, approximately 800 feet downstream of the property. Each stream gauge benchmark was surveyed in the same manner as the monitoring wells in order to determine their reference elevations and location coordinates. Stream elevations were then able to be determined at these locations using an electronic depth-to-water meter or by a direct read of the staff gauge. In addition, a continuous level recorder was installed at SG-2. This recorder was installed in a stilling well that was made from PVC pipe and mounted vertically on the Outfall 001 stair supports. It was programmed in a similar fashion as the continuous level recorders installed in the site monitoring wells/piezometers, and referenced off of the SG-2 benchmark established at the



stair handrail. Data from this level recorder were managed in the same fashion as the data from the well clusters.

To evaluate the potential impacts of precipitation events on groundwater elevations, a recording rain gauge (manufactured by Global Water) was also installed at the site. This rain gauge features a tipping bucket design with an integral microprocessor-based data logger. It is capable of recording as little as 0.01 inches of rainfall. It was programmed to record the amount of precipitation that falls every hour; if there is no measurable precipitation over the course of a day, the program defaulted to logging a zero for that day (rather than by hour).

The continuous water level recorders, stream gauges and rain gauge were installed at the end of October 1998, immediately following the completion of the first round of groundwater sampling. On December 1, 1998, which was approximately one month after installation of the continuous level recorders and rain gauge, the data collected to that point was downloaded from all site data loggers. This was done to verify the proper operation of all units, and to obtain an initial indication of the short-term variability at each monitoring location. After downloading this initial month of data, the data loggers were reset for ongoing monitoring. Recorded data was then downloaded during subsequent site visits, including when quarterly groundwater monitoring samples were collected. Data collection continued through November 1999 in order to obtain at least twelve months of continuous monitoring data.

Data and graphs from the continuous level monitoring are presented in Appendix G.

2.4 Borehole Geophysical Investigation

On October 8, 1998, Appalachian Geophysical Surveys of Apollo, Pennsylvania performed a series of downhole geophysical tests on the former Production Well 947. The purpose of these tests was to determine if this former production well (which has been out of service for many years) could have served as a piezometer for monitoring static water levels within the bedrock aquifer. For the well to serve this purpose, there would need to be no communication between the overlying unconfined aquifer and the bedrock aquifer as a result of poor casing integrity or inadequate casing sealing. The tests that were performed included the following:

- Downhole video camera survey
- Full wave sonic logging
- Temperature, conductivity, spontaneous potential and resistance logging
- Caliper, gamma/neutron and gamma/density logging

Copies of the survey report and the logging charts are presented in Appendix D.

These test results indicated that the overburden aquifer is in communication with the bedrock aquifer at former Production Well 947. This is primarily illustrated on the full-wave sonic log provided in Appendix D, which indicates that the steel well casing was probably not cemented in place. It was probably driven into the ground using cable-tool methods typical of well installation techniques at the time the well was installed. It may then be presumed that overburden aquifer water may flow downward (or bedrock aquifer water may flow upward) along the outside of the casing. The temperature and neutron porosity logs indicate a probable flow zone at the bottom of



the casing, which also supports this hypothesis. The casing itself was found to be intact.

Given these findings, it was judged that Production Well 947 could not serve as a suitable monitoring point for the piezometric surface in the bedrock aquifer.

An attempt was then made to place a piezometer within the existing steel well casing with a seal below the end of the casing. This piezometer would have utilized a shale trap as a seal. The shale trap consisted of a rubber conical device that would expand to form a seal at the edge of the borehole by placing bentonite above it. A 2-inch diameter PVC riser would then complete the piezometer to the surface, with the annular space filled with bentonite grout.

As the shale trap was being lowered, its downward movement was stopped just before the bottom of the steel casing. The well casing may have been dented at that point as it was being driven into place (although the caliper log did not reveal such an obstruction). Attempts to pound the PVC casing and shale trap past the obstruction resulted in a section of the PVC casing breaking off at a considerable depth inside the existing steel casing. After this occurrence, and based on other information obtained during the RFI (e.g., the hydrogeologic modeling discussed in Section 5 of this report), the attempt to install a bedrock piezometer was deemed to be unnecessary and was abandoned.

2.5 Well Sampling and Water Level Measurements

After allowing the newly-installed wells to stabilize for several days, the first round of quarterly sampling was performed, beginning on October 29, 1998. Prior to sampling the wells, a depth-to-



water measurement was taken at each well (new and existing) and piezometer, and standard field parameters (pH, conductivity, temperature and Eh) were measured using properly-calibrated portable field instruments. The wells were then purged using a PVC bailer that was decontaminated prior to use in each well. Purging consisted of removing a minimum of three well volumes of water or until the well was dry. Purge water was placed into drums, pending the results of the groundwater analyses. Field parameters were periodically monitored during purging. After purging was completed, the field parameters were again measured and recorded to verify that stable conditions had been achieved.

Each well was then sampled using dedicated, disposable polyethylene bailers and nylon cord. Samples for dissolved metals analysis were field filtered using disposable 0.45 μ filters and a hand pump. Collected samples were placed into pre-preserved and pre-labeled bottles provided by the laboratory (Lancaster Laboratories). Samples were then chilled using ice packs in coolers and shipped via overnight courier under appropriate chain-of-custody to Lancaster Laboratories. Special care was taken so that the 24-hour holding time for hexavalent chromium analyses was not exceeded. However, the initial samples from MW-6 through 10 were received by the laboratory after the 24-hour holding time had expired. These wells were immediately resampled, and the samples were shipped to the laboratory and analyzed within the specified holding time.

At the laboratory, the samples were analyzed in accordance with Section 3.2.1.3 of the RFI Workplan. Samples from the newly-installed wells were analyzed for the Abbreviated Appendix VIII List parameters, while samples from the existing wells were analyzed for dissolved trivalent and dissolved hexavalent chromium.



In addition to the groundwater samples, quality control samples were also prepared in accordance with the Data Collection Quality Assurance Plan in the RFI Workplan. These samples consisted of a trip blank, equipment rinseate blanks, and a duplicate of the sample from one of the new monitoring wells⁴. The quality control samples were handled in the manner described above for the groundwater samples.

Subsequent quarterly monitoring was then conducted at the site, beginning on the following dates:

- Round 2: February 1, 1999
- Round 3: May 10, 1999
- Round 4: August 2, 1999

Monitoring during these subsequent rounds was generally performed in the manner described above, with the following exceptions that were noted in Section 6 of the Interim RFI Summary Report:

- In accordance with Section 3.1.2 of the RFI Workplan, the collected samples were only analyzed by the laboratory for the Potentially Elevated Parameters, dissolved hexavalent chromium and dissolved trivalent chromium. The method used to determine the Potentially Elevated Parameters is described in Section 4.1 of this report.
- In accordance with Section 3.1.2 of the RFI Workplan, the number of wells that were sampled was reduced. For Rounds 2, 3 and 4, only monitoring wells MW-2, MW-7, MW-8, MW-9, MW-11, MW-13, and MW-14 were sampled. At the request of U.S. EPA, monitoring wells MW-6 and MW-10 were also sampled during Round 4.

⁴ A different well was selected for duplicate analysis for each monitoring round.



Additional water level elevation measurements were obtained at all monitoring locations during site visits that were conducted on December 1, 1998, October 11, 1999 and December 6, 1999. Water elevation data is presented in Table 1.

As stated in Section 5.2 of the RFI Workplan, the data from this investigation is not considered to be Level 4 (CLP Level data). Therefore, a formal data validation procedure was not performed. However, all data (including the results of quality control samples and the laboratory quality control reports) and field procedures were closely reviewed by the Quality Assurance Officer to determine if any abnormalities existed that could cause the data to be suspect.

2.6 Human Receptor Characterization

As stated in Section 2.2.5 of the Existing Conditions Report, several area businesses and residences have a water supply waiver with Wellsboro Borough. This waiver exempts the borough from providing water service to that address

As part of the RFI, efforts were taken to obtain further information regarding private water supply wells downgradient of the site (i.e., to the north and west), since such wells could serve as a potential human exposure pathway to groundwater contaminants. Specifically, this task focused on attempting to determine the existence and locations of downgradient private wells, and determine the formation and/or elevation of the water bearing zone(s). This information would then be used to determine if it was possible for interconnections to exist between the on-site overburden aquifer and the water-bearing zones of the downgradient private wells.



Several resources that maintain records of well installations were contacted to obtain information regarding private wells in Wellsboro Borough and within a one-mile radius of the downgradient portion of the site (using MW-12 as the reference location). These resources include the following:

- Tioga County Department of Emergency Services.
- Pennsylvania Department of Conservation and Natural Resources.
- Wellsboro Water Authority.
- Pennsylvania Geologic Survey and the United States Geologic Survey, via a database search service (Environmental Risk Information & Imaging Services).
- A local well drilling firm, Andrews Well Drilling, Inc.

The information that was obtained from these resources included the well location, owner of record, installation date, total depth, casing length, geologic formation of the water-bearing zone, and yield. Note that all information was not available for every identified well. Using this information along with other available topographic data, the elevation of the private well water-bearing zones and the distance to the wells were calculated. This information has been tabulated and plotted on Figure 7. This map also presents the location of the downgradient properties with water supply waivers identified in Figure 2-5 of the Existing Conditions Report.

The nearby private water supply wells are discussed again in Sections 3.7 and 5.0 of this report.



2.7 Ecological Assessment

The field survey portion of the ecological assessment described in Section 3.2.6 of the RFI Workplan was completed on October 19 and 20, 1998 by Keith Maurice and George Christian, Project Biologists. The main objective of the survey was to identify possible environmental receptors for potentially contaminated groundwater. The study area for the ecological assessment, which is shown on Figure 1 in Appendix F, encompassed Charleston Creek from where it crosses U.S. Route 6 in Charleston Township, to its confluence with Marsh Creek in the Borough of Wellsboro. The study area also included the lower sections of two small unnamed tributaries to the creek that enter the study area from the north. These streams were designated as the western and eastern tributaries and their study areas extended approximately 100 feet upstream from their respective confluences with Charleston Creek. In addition, the study area included an input zone extending approximately 300 feet from each bank of all three streams.

During the survey, qualitative samples of fish and aquatic macroinvertebrates were collected with a seine and kick net, respectively, at four sample stations spread equally within Charleston Creek. Fish and aquatic macroinvertebrates were collected according to methods adapted from the U.S. Environmental Protection Agency (1989). From 7 to 10 hauls were made by seine at each station to collect fish. Fish specimens were identified to species, enumerated, and immediately returned to the stream. Macroinvertebrates were collected by disturbing the substrate at three sublocations at each station for 60 seconds (timed with a stop watch) and allowing the current to wash dislodged specimens into the net. Flow was simulated in shallow pools by passing the net through the disturbed area. The samples were then placed in a gridded pan from which 100 or more specimens were removed from randomly selected grids, identified to family, and enumerated.



As a result of dry conditions, the western tributary near its confluence had virtually no flow or pools of standing water that could be sampled. Therefore, no fish or benthic macroinvertebrate samples were collected at this location. The eastern tributary also had no flow near its confluence; however, aquatic macroinvertebrates were sampled from several shallow pools.

The macroinvertebrate data were reduced to a set of three ecological metrics to facilitate descriptions of the community. They were: 1) the total number of taxa present (richness); 2) the number of taxa present within the three insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) considered to be pollution sensitive; and 3) the ratio between the number of EPT insects and insects within the family Chironomidae (EPT/Chironomidae ratio), considered to be pollution tolerant.

The field survey also included a reconnaissance of the input zone to identify and qualitatively describe general ecological features, including flora and fauna, animals, wetlands and riparian habitats, stressed vegetation and visible point and non-point drainage into the streams. Specimens of plants that could not be identified in the field were collected and returned to the laboratory for identification with dissection microscopes and taxonomic keys. There was no collection of wildlife specimens. Representative photographs were taken of each sample station on Charleston Creek, and of the vegetation communities and land uses in the input zone. Appendix F includes tabulated lists of the identified plant and animal species from the study area.

Wetlands were identified and documented in accordance with the U.S. Army Corps of Engineers' 1987 Wetlands Delineation Manual (Corps' Manual). The Corps and Pennsylvania Department of Environmental Protection (PaDEP) currently require application of the methodology presented in



the Corps' Manual to identify and delineate the boundaries of wetlands under their jurisdiction. During the input zone survey, each plant species was rated according to its overall dominance and its frequency of occurrence in wetlands, as determined by the U.S. Fish and Wildlife Service (see Table 1 in Appendix F). Soils were examined with the use of a hand auger and interpreted for hydric characteristics using Munsell soil color charts. Evidence of wetlands hydrology as outlined in the Corps' Manual was noted.

In addition to the field survey, several agencies responsible for the management of plants and wildlife in Pennsylvania were contacted regarding the presence of threatened, endangered or rare species within the defined study area. Such agencies included the following:

- Pennsylvania Department of Conservation and Natural Resources
- Pennsylvania Game Commission
- Pennsylvania Fish and Boat Commission

Copies of correspondence from these agencies are also included in Appendix F.

2.8 Aquifer Testing and Analysis

2.8.1 Preliminary Slug Tests

The RFI Workplan calls for the performance of a long-term pump test (approximately 48-hour duration) in the shallow aquifer in order to establish aquifer characteristics that could be used in fate and transport calculations. In order to estimate the maximum expected pumping rate, rising-



head slug tests were performed on December 3, 1998 on three site monitoring wells that were under consideration to be used as the pumping well: MW-8, MW-9 and MW-12. The slug tests involved lowering a “slug” into the well, which caused the static water level to temporarily rise. The slug consisted of a 28-inch long section of 1-1/4-inch diameter PVC casing that was filled with silica sand and capped on both ends. After the water level returned to normal, the slug was withdrawn, and the water level in the well dropped. The rate at which the water level rose following the removal of the slug was monitored with a pressure transducer and data logger (Campbell Scientific, Inc. PST8 Pump Test and Slug Test data logging system). The test was completed for a given well after the water level returned to about the original elevation. The collected water level data was analyzed using the Hvorslev method for rising-head slug tests. This analysis resulted in an estimate of the hydraulic conductivity and yield for each well. MW-8 was then selected as the well to be used as the pumping well for the pump test, since it was judged to best satisfy three criteria: 1) it had a reasonable yield, 2) it had no elevated concentration of any contaminants, based on Round 1 sampling (discussed later in this report), and 3) there were other nearby wells by that could possibly be used as observation wells during the test. Also, the target pumping rate for the pump test was established at 3 to 4 gallons per minute (gpm), with an expected maximum pumping rate of 8 gpm. The slug test data and calculations are provided in Appendix E.

2.8.2 Pump Tests

In order to perform the shallow aquifer pump test, it was first necessary to obtain approval from PaDEP to discharge the pumped water to Charleston Creek via Outfall 001 which is regulated under the facility’s NPDES Permit. Mr. Richard Adams of the PaDEP’s Northcentral Regional



Office in Williamsport, Pennsylvania was advised of the Round 1 analytical results and the target and maximum pumping rates. Using this data, PaDEP established temporary discharge limits of 0.35 mg/l for hexavalent chromium and 1.0 mg/l for arsenic based on acute water quality criteria. A letter from PaDEP communicating these limits is included in Appendix E.

Due to adverse winter weather conditions that existed following receipt of the temporary discharge limits, the pump test was delayed and first attempted beginning on April 12, 1999. At that time, a 48-hour pump test was attempted by pumping water from well MW-8. However, equipment malfunctions produced fluctuations in the pumping rate; attempts were made to analyze the data from this initial test, but the data could not be analyzed successfully. The pump test was therefore repeated, beginning on October 11, 1999. PaDEP was informed that the test was to be repeated prior to commencement of field activities.

At the beginning of the test, water levels were obtained at all monitoring locations using an electronic depth-to-water meter (see Table 1). Next, the pump test equipment was set up at the pumping well (MW-8) and calibrated. The equipment consisted of a Grunfos Redi-Flo 2 submersible pump, which was powered by plant electricity. An electronic flow meter was installed on the discharge of the pump, in order to allow the field personnel to precisely maintain the desired flow rate (6.3 gpm⁵) throughout the test. This meter also included a totalizer to measure the total volume pumped during the test. Pumped water was discharged through Outfall 001 via a plant drain.

⁵ This target flow rate was slightly higher than the target rate established through the preliminary slug test data analysis based on results of the first pump test.



Pumping for the second 48-hour constant-rate pump test initiated at 11:25 AM on October 12, 1999. The pumping well (MW-8) was pumped at 6.3 gpm; only minor fluctuations in the pumping rate occurred throughout the test (see Appendix E).

During the pump test, water-level measurements at MW-8 were initially recorded at intervals of 30 seconds, and then less frequently as the test progressed. Water level readings were also closely monitored at nearby observation wells MW-6, MW-9, MW-13 and piezometers P-1 and P-3. A full round of water levels was recorded near the end of the 48-hour pumping period. Barometric pressure readings were also taken during the test, as were precipitation measurements. The pump test continued for 48 hours (through 11:30 AM on October 14, 1999), at which time the pumping ceased and recovery phase data was collected. Rainfall occurred during the second half of the test from October 13th at 7:45 P.M. until October 14th at 7:30 A.M.; during this time, approximately 0.31 inches of rain was measured using the on-site rain gauge.

Midway through the pump test, a sample of the combined flow being discharged at Outfall 001 (which included the pump test water) was obtained at the request of PaDEP. This sample was analyzed for hexavalent chromium and total arsenic, in order to verify that the temporary effluent limits established for the pump test were satisfied. Results of these analyses were as follows: hexavalent chromium concentration - less than 0.005 mg/l; total arsenic concentration - 0.005 mg/l. Both results are less than the PaDEP-specified temporary discharge limits. A copy of the laboratory data sheet for these analyses is included in Appendix E.

A total of 24.97 feet of drawdown occurred in pumping well MW-8 at the end of 48 hours of pumping. Drawdown noted at the observation wells ranged from +0.46 to -0.46 feet (see



Appendix E). The level increase noted in some of the wells was the result of infiltration from the precipitation that occurred during the test. The test data for wells MW-6, MW-8 and MW-9 were primarily used to determine the aquifer parameters of the overburden aquifer at the site. The data collected at these wells was best suited for analysis since the wells are all constructed in a similar manner as well MW-8; these wells are all “midrange” wells that were installed using 30-foot long screens. In addition, wells MW-6 and MW-9 are located approximately 95 and 230 feet from well MW-8, respectively, and are located in paved areas which were not significantly affected by the precipitation that occurred during the test. Drawdowns of 0.40 and 0.18 feet were measured at wells MW-6 and MW-9, respectively, at the end of the pumping period.

The pumping test data was analyzed using three methods: 1) the Jacob Straight-Line method, 2) the Distance-Drawdown method, and 3) the Residual-Drawdown Straight-Line method.

All pump test data and calculations are included in Appendix E.

2.8.3 Groundwater Gradients

Table 1 presents the water elevation data obtained during the various monitoring events. Groundwater contours of the shallow overburden aquifer were determined using the data from the four quarterly monitoring events and Golden Software’s SURFER program (version 4.15). Key input parameters to the GRID subroutine were determined after several iterations to produce the most reasonable interpretation of groundwater data, and are as follows:



- Handling of duplicate data points: Average
- Grid node spacing: 20 feet in both X and Y directions
- Gridding method: Kriging
- Search method: All points
- Search radius: 1000 feet
- Number of nearest points: 10

Initially, the groundwater contours were plotted using Round 1 data only from the shallow monitoring wells (MW-1, 2, 3, 11, 12, 13 and 14). Next, the stream gauge elevations were compared to the predicted groundwater elevation at each location based on the shallow well contours. In each case, the actual stream elevation was less than the predicted groundwater elevation at that point. This suggests that the stream was receiving flow from the shallow aquifer, as expected. Given this information, SURFER was re-run using both the stream elevations as well as the shallow well groundwater elevations. Following this additional SURFER trial, additional stream elevations were interpolated for the reach of the stream between SG-1 and SG-2 (since there was so little control in this area), and the plotted contours were adjusted slightly near the stream. The resultant shallow aquifer groundwater contours are shown on Figure 3A.

The procedures described above were repeated for the water level information collected during monitoring Rounds 2, 3 and 4. The resultant groundwater contours are shown on Figures 3B, 3C and 3D, respectively.

Next, vertical gradients were calculated at the existing “midrange” wells, the deep wells and piezometers. Vertical gradients were determined by subtracting the actual measured groundwater



elevation at a given well location from the predicted groundwater elevation at that point as determined by the groundwater contours plotted using only shallow well and stream elevations. Where well clusters existed (e.g., MW-2 and P-1), the actual measured groundwater elevation in both the shallow and deep well or piezometer were used to calculate vertical gradients. A negative sign in the result indicates a downward gradient; a plus sign indicates an upward gradient. The results of these calculations for all four monitoring rounds and the December 1, 1998 site visit are presented in Table 2.

During the initial analysis of groundwater elevation data from Round 1, an evaluation was then made as to whether data from the existing "midrange" wells (MW-6, 8, 9 and 10) could be used in the determination of shallow groundwater horizontal gradients. It was speculated that data from these wells may be useful for this purpose, given the fact that the wells are screened across the water table surface. However, since the midrange wells have excessively long screen lengths (30 feet), there was a concern that vertical gradients that might exist within the overburden at these locations could cause the measured elevations to be unrepresentative of the uppermost groundwater surface and thus skew the contours. Based on the results presented in Table 2, small vertical gradients (less than one foot) were calculated at each of these points. However, a SURFER trial was performed which included the midrange well data. The resultant groundwater contours were not significantly different than those calculated with only the shallow wells and stream elevations. However, the plotted contours were judged to be slightly less representative than those shown on Figure 3A due to some bunching of contour lines in the vicinity of the midrange wells. Therefore, it was decided to exclude the midrange well elevation data from the groundwater contour determinations.

3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

3.1 Surface Features

Figure 2 depicts a plan of the major surface features at the OSRAM facility. Manufacturing areas are bordered to the south by an industry-owned rail spur, to the west by Jackson Street and to the north and east by Charleston Creek. A security fence surrounds the manufacturing areas. The only ready access to the manufacturing area is through a security gate on Jackson Street. Additional small property segments are located to the east of Charleston Creek, to the west of Jackson Street and south of the rail spur. The areas west of Jackson Street and south of the rail spur are used for employee and visitor parking. The area east of Charleston Creek is undeveloped and wooded.

The manufacturing area consists of two two-story structures which house the glass furnace, the ribbon machines and the automated frost (acid etching) line. Basements to these structures contain the ribbon machine cooling water basins, the small chrome plating operations plus miscellaneous storage. Adjacent to these structures is a two-story administrative office building. There is also a complex of single-story structures which house conveyer systems for the central packing operation, a smaller batch frosting operation, the bulb coating operation, parts stores, maintenance shops and warehouses. The yard area west and north of the buildings is partially paved. Various raw material handling and storage equipment, utilities and waste management facilities are located throughout the yard.



Two NPDES-permitted discharges from the facility are present on Charleston Creek. Outfall 001 is a discharge for combined process water and storm water. Outfall 002 discharges only storm water.

3.2 Geology / Soils

3.2.1 Regional Geology

The facility is located in the Appalachian Plateau Geologic Province. The Appalachian Plateau Province is underlain by a sequence of Paleozoic age sedimentary rock up to 15 kilometers thick. Typically, the rocks in the province are gently folded and often nearly flat-lying. The facility lies on the northwestern flank of the southwest-northeast trending Wellsboro anticline. Therefore, the rocks beneath the site generally dip to the northwest at an unknown (but most likely very low) angle.

The Devonian-age Lock Haven Formation underlies the site and is exposed in the Wellsboro area along the anticlinal axis and in the stream valleys along the structural flanks where the younger strata have been eroded. The Lock Haven Formation is a predominantly fine-grained series of interbedded siltstones and shales, with some fossiliferous sandstone that may be locally conglomeratic. Joints in the formation are poorly to well developed and moderate to widely spaced. The thickness of the formation at the site is unknown, but in Lycoming County, south of the site, it attains a maximum thickness of 4,460 feet.

The Devonian-age Catskill Formation overlies the Lock Haven Formation and may crop out along



the anticlinal flanks. Locally, the Catskill Formation is divided into Irish Valley Member and the overlying Sherman Creek Member. The Irish Valley Member consists of cyclic sequences of marine and non-marine sandstone, siltstone, and shale. The marine deposits are primarily olive gray in color and fossiliferous, and the non-marine deposits are red. Joints are well developed, closely spaced and highly abundant. The Sherman Creek Member consists primarily of interbedded shale and siltstone, with minor amounts of micaceous, cross-bedded sandstone. Joints are well developed, unevenly spaced, and highly abundant. The thickness of this unit in the area reportedly ranges from 1,200 to 2,000 feet.

The major erosion valleys in the area were primary outlets of glacial outwash during the Pleistocene glaciations. In addition, periodic ice blockage of the streams resulted in the formation of large lakes. Consequently, the valleys are filled with glaciofluvial and glaciolacustrine deposits that reportedly may exceed 200 feet in thickness.

Two US Department of Agriculture-classified soil types predominate in the Charleston Creek valley near the facility. The Pope Series occupies approximately 90 percent of the area. Pope Series soils are deep and well drained, and normally found on flood plains. In a typical profile, the surface layer is seven inches thick and consists of a dark brown, fine-grained, sandy loam. The subsoil, which extends to a depth of 46 inches, is a dark brown friable loam. The substratum extends to a depth of 66 inches and is a dark yellowish-brown sandy loam. Pope soils are relatively permeable to very permeable (10^{-4} cm/sec to greater than 10^{-3} cm/sec). They are medium to strongly acidic (6.0 to 5.1 pH) in the surface layer and strongly to very strongly acidic (5.5 to 4.5 pH) in the subsoil and substratum.



The Wyoming Series occupies the remaining 10 percent of the area. These soils are deep, excessively drained soils that form on glacial outwash terraces. In a typical profile, the surface layer is seven inches thick and consists of a dark grayish-brown gravelly sandy loam. The subsoil, which extends to a depth of 30 inches, is a dark yellowish-brown to brown, very friable, very gravelly, sandy loam. The substratum, which extends to a depth of 80 inches, consists of stratified sand, gravel and cobblestones. Wyoming Series soils are very permeable (greater than 10^{-3} cm/sec) and are medium to strongly acidic (6.0 to 5.1 pH).

These near-surface soils probably have been disturbed across much of the site due to historical construction and excavation activities associated with plant development.

3.2.2 Site Geology

Information from the previously-existing monitoring wells, seven previous soil borings, the three former production wells and the soil borings performed during the RFI has been used to develop the following description of the unconsolidated deposits immediately below the facility. The surficial geology at the facility consists of natural alluvium and localized fill areas. The natural alluvium soils generally consist of fine to coarse-grained sand and gravel glacial tills with varying amounts of silt. The fill materials consist of silt, sand, gravel, and some man-made materials such as fire brick, tile and glass. The thickness of fill materials deposited across the majority of the site ranges from 0 to 18 feet. The natural soils to a depth of 15 feet are distinctive in color (red brown) and dark-brown to gray to the top of the consolidated rock. The deeper natural soils are generally glaciofluvial and glacio-lacustrine deposits consisting of washed glacial tills containing more gravel. Available information suggests the thickness of the overburden materials ranges from 14 to 74 feet.



The first-encountered bedrock is believed to be the Devonian-age Lock Haven Formation. Based on rock cores obtained at the site, it was found to be predominately gray to dark gray siltstone, ranging from medium hard to medium soft, along with some gray, hard, fine-grained sandstone. Calcareous zones, consisting of limestone banding and nodules with slight to strong fizz test reactions (using 2 percent hydrochloric acid solution), were also encountered in the siltstone units. Horizontal fracturing was evident in the siltstone unit, with RQDs ranging from poor to fair. Refer to the boring logs presented in Appendix B.

The geologic cross-sections shown on Figures 5 and 6 depict the occurrence of bedrock across the site. Along the southern property line, and furthest from Charleston Creek, bedrock was identified at an average depth of approximately 65 feet. Previous borings had indicated bedrock occurring as deep as 74 feet. The depth to bedrock gradually decreased with proximity to the Creek. At the monitoring location closest to the creek, bedrock was encountered at a depth of only 14.5 feet, which is only about 4 to 6 feet below the bottom elevation of Charleston Creek. These findings are consistent with regional geologic information.

3.3 Hydrogeology

3.3.1 Regional Hydrogeology

Past studies referenced in the Existing Conditions Report noted that glacial deposits are not an important aquifer in the site vicinity. According to the information reviewed during the RFI, all of the wells in Wellsboro Borough tap the Devonian-age Lock Haven Formation (also known as the



Chemung Formation). The Lock Haven Formation is generally a marginal to fair yielding bedrock aquifer, both regionally and locally. Water produced from the Lock Haven Formation is moderately hard and relatively high in dissolved solids. High levels of iron and manganese are common.

Regionally, glacial valley fill deposits are important sources of water. Glacial sands and gravels typically are very well sorted, retain their primary intergranular porosity, and have high hydraulic conductivities. Glacio-lacustrine deposits are typically finer grained and have lower primary porosities and hydraulic conductivities. However, there is no record of current development and use of the glacial deposits in the vicinity of the site. At one time, Corning Glass Works had reportedly explored the glacial deposits as a water source to supplement municipal water supplies.

A pump test was performed for Corning Glass Works in 1963 on three existing wells located approximately 1.5 miles north of the plant. An 8-hour pump test was performed on an unscreened 124-foot deep well, and resulted in an estimated transmissivity of 70,000 to 89,000 gpd/ft. However, the transmissivity of the unconsolidated aquifer at the site appears to be one order of magnitude smaller than the deposits tested by Corning Glass Works (See Section 3.3.2).

3.3.2 Site Hydrogeology

Groundwater contours plotted for the shallow overburden aquifer indicate that groundwater flow across the site is generally towards the northwest. This is consistent with groundwater data collected during earlier studies. The average horizontal gradient (dh/dx) across the site is approximately 0.017 feet/foot, based on the plotted groundwater contours.



Vertical gradients have been identified within the overburden aquifer at the site. Near the former drywell location (at the southern property boundary and distant from Charleston Creek), the vertical gradient was downward, with a measured magnitude averaging approximately 3.0 feet⁶. The gradient reverses closer to Charleston Creek and becomes upward near the creek, with the average upward gradients calculated to be 0.45 feet at MW-13 / P-3. These gradients would likely create the simplified flow patterns within the overburden aquifer depicted on the geologic cross-section shown as Figure 5. However, it should be noted that lower permeability units encountered at depth probably restrict the actual downward vertical flow of groundwater within the overburden aquifer at the site.

Based on the interpretation of the groundwater gradient data presented herein, Charleston Creek is serving as a local discharge point for the shallow overburden aquifer, and acts as a groundwater flow boundary. Moreover, these conditions indicate that any residual chromium in the site groundwater from the former drywell operation will migrate to the north or northwest, and towards one or more of the monitoring wells at the site.

Appendix G presents the results of the continuous water level and rainfall monitoring. The following observations may be noted from these results:

- Vertical gradients identified during the quarterly monitoring events were generally consistent throughout the study period. An apparent vertical gradient reversal at MW-14 /

⁶ The measured magnitude of the vertical gradient is the difference between groundwater elevations at MW-2 and P-1. See Table 2.



P-4 which occurred is believed to be the result of periodic malfunction of the electronic level logger unit in MW-14.

- The occasional fluctuating logger data observed in MW-14, P-1 and P-4 do not coincide with one another, as would be expected if the fluctuations were caused by an real, external influence (e.g., a nearby pumping well). As described elsewhere in this report, there are no known pumping wells in the vicinity of the facility. Therefore, it appears that the fluctuations are probably anomalous signals and are not representative of true site conditions.

The late-term drawdown measured at wells MW-6 and MW-9 during the 48-hour pump test was analyzed according to the Jacob Straight-Line method. This yielded transmissivity values of 8,710 and 8,190 gpd/ft, respectively. A distance-drawdown analysis performed using data for well MW-6, MW-7 and MW-9 yielded a transmissivity of 7,020 gpd/ft. Finally, the recovery data for wells MW-6 and MW-8 were analyzed by plotting the residual drawdown measured at each well versus the log of t/t' . This analysis determined transmissivities of 10,390 and 8,270 gpd/ft at wells MW-6 and MW-8, respectively.

The average transmissivity determined using all the methods described above is 8,516 gpd/ft, which is equivalent to a value of 1,139 square feet per day (ft^2/d). The overburden thickness in the vicinity of wells MW-6 MW-8 and MW-9 is approximately 50 feet. A hydraulic conductivity of 23 ft/d was calculated from the average transmissivity and overburden aquifer thickness at the site. An average storativity value of 0.009 was determined during the analysis of the test data; this value is low for an unconfined aquifer, and suggests that semi-confined conditions may occur within the overburden aquifer.



The site hydrogeology is discussed again in Section 5.0 of this report.

3.4 Surface Water Hydrology

The facility lies within the Glaciated Low Plateaus Section of the Appalachian Plateaus Physiographic Province. This province is topographically characterized by a series of uplifted, dissected plateaus. The drainage pattern is dominantly dendritic and the major tributaries have eroded broad, deep, steep-sided valleys. Relief along the valleys in the immediate Wellsboro area is generally less than 300 feet.

The facility is situated in the Charleston Creek stream valley. Hamilton Lake, which is a man-made lake, is located along Charleston Creek approximately 1-1/2 miles east (upstream) of the facility. This lake was constructed in the early 1970's for flood control purposes; thus the discharge from Hamilton Lake (and therefore, the flow in Charleston Creek at the site) is regulated. The lake also provides a portion of the water supply for Wellsboro Borough.

Downstream of the facility, Charleston Creek flows northwest and joins with Kelsey Creek approximately one-half mile northwest of the site to form Marsh Creek. Charleston Creek is part of the Pine Creek drainage basin. The stream bed of Charleston Creek is believed to have been shifted eastward to accommodate site development sometime between the 1946 and 1986, when from 6 to 18 feet of earthen fill was added to bring the eastern portions of the site to current grade.

Storm water runoff from the site ultimately drains to Charleston Creek. Storm water runoff in the manufacturing area is conveyed northward via a network of roof drains and catch basins that



ultimately discharge to Charleston Creek through Outfall 001 or Outfall 002. The eastern perimeter of the site drains via overland sheet flow directly to Charleston Creek or to a drainage ditch that flows to Charleston Creek. The western and northwestern perimeter of the site drains to Jackson Street or directly to Charleston Creek via overland sheet flow.

3.5 Climate and Meteorology

The Wellsboro area is characterized by a temperate climate. The average annual mean temperature is 45°F, with a mean January temperature of 21°F and a mean July temperature of 67°F. The average annual precipitation is 40.8 inches, and the average annual evapotranspiration is 36 inches (NTRPDC, 1993; NOAA, 1999). Prevailing winds are generally from the west, although severe weather is often accompanied by more easterly winds.

The data from the recording rain gauge that was operational during the RFI is presented graphically in Appendix G. This graph includes twelve months of data (from November 1998 through October 1999). The data indicates that the peak daily precipitation event was 1.69 inches of rainfall, and that a total of 24.2 inches of precipitation was recorded during the 12-month RFI study period. These data are reflective of the severe drought conditions that existed during the RFI.

3.6 Land Use and Demography

Land use surrounding the facility is a mixture of industrial, commercial, residential and rural uses. Areas immediately southeast of the plant are primarily industrial in nature, occupied by a Borden,



Inc. dairy products plant and a former furniture refinishing operation. A residential area is located approximately 200 feet farther to the south, in the highlands near and across U.S. Route 6.

The primary business and residential sections of Wellsboro are located west of the facility. Immediately northwest of the facility, the Charleston Creek valley supports an area of industrial and commercial development. A Wellsboro Electric Company substation, shops and offices for a short line commercial and scenic railroad, a construction materials company, and various other commercial establishments are located here.

Areas north and east of the facility are generally rural and undeveloped with a few residences located along Charleston Street, Buena Vista Avenue and other intersecting roads. A former landfill used by the Corning Glass Works is located immediately northeast of the plant on the far side of Charleston Creek. The landfill has been closed and the area has been converted into a recreational area (ballfield).

The Wellsboro Municipal Water Authority serves the Borough of Wellsboro and a small area of Charleston Township. The authority obtains groundwater from a network of 23 wells and 13 springs located near the community of Brownlee, which is approximately 6 miles south of the site. Surface water is obtained from intakes along Willis Run, (located 2.8 miles southeast of the site), Charleston Creek, (located 2.9 miles southeast of the site), and Hamilton Lake, (located 1.3 miles southeast of the site). These sources are all hydraulically upgradient from the site. The groundwater and surface water supplies are integrated before treatment and are stored in reservoirs located within the borough, approximately 0.5 mile south and upgradient of the site. The Wellsboro Municipal Water Authority distribution system is gravity-driven and cannot deliver



water to elevations higher than approximately 1,450 feet. In 1991, it was reported that the Wellsboro Municipal Water Authority serves a population of 3,800 people.

Additional demographic data for Wellsboro and Tioga County were provided in Appendix D of the RFI Workplan.

3.7 Potential Receptors, Habitats and Exposure Pathways

Although the available information indicates that there are a few domestic wells located northwest of the site across Charleston Creek, the hydrogeologic conditions at the site exclude the owners of these wells as potential receptors of contaminants in the overburden aquifer. More specifically, the modeling described in Section 5 and the observed vertical gradients in the overburden aquifer identify Charleston Creek as a discharge point for the shallow aquifer (a hydraulic boundary). In addition, there are no known water supply wells downgradient of and on the same (southern) side of Charleston Creek as the facility, nor are there any known water supply wells in the immediate vicinity of the facility in any direction. These factors rule out several potential human exposure pathways (U.S. EPA 1989), including ingestion or inhalation of impacted groundwater, dermal contact with impacted groundwater, and consumption of fruits or vegetables watered with impacted groundwater.

Other potential human exposure pathways involve contact with Charleston Creek after impacted overburden groundwater discharges into it. However, information gathered during this RFI also rules out these potential human exposure pathways. Charleston Creek is not used for water supply or recreational purposes (e.g., swimming, fishing, boating) downgradient of the site. This



eliminates the potential exposure pathways of ingestion of and dermal contact with impacted surface water, and consumption of fish from impacted surface waters. Thus, there are no viable human exposure pathways for identified contaminants in the site groundwater. The Charleston Creek ecosystem therefore is primary potential receptor for risk assessment purposes. Since the site itself is an active manufacturing area, it has virtually no value as a habitat for wildlife, and there are no ecological receptors of concern in the active manufacturing area.

Charleston Creek is a third-order tributary to the Susquehanna River via Marsh Creek and Pine Creek. The stream follows a sinuous course through most of the study area, but is channelized and bulk headed at the western end. The stream has a riffle-run-pool nature and is overtopped by a forest canopy along much of its length. Channel width varies from approximately 40 to 50 feet, but the wetted channel width was only 5 to 15 feet during the ecological assessment field survey. Generally, the stream was only a few inches deep in most places except for a few deeper runs and pools. The substrate typically consisted of a variable mixture of cobbles, gravel, sand and silt, with boulders and bedrock in some reaches. The stream bottom was about 90-percent covered with periphyton. A large quantity of decomposing leaf detritus also was present in pools and backwaters at the time of the ecological assessment (October 1998).

Within the study area, the western and eastern tributaries have formed largely straight channels 10 to 20 feet wide. The streams had a scoured appearance, and most of their flow likely occurs as storm water runoff. The western tributary is little more than a roadside ditch and flows through several culverts near its confluence with Charleston Creek. Its banks consisted of mowed herbaceous vegetation and there was virtually no flowing water during the field survey. The eastern tributary had a moderately entrenched channel and also flowed in the vicinity of a road. Its

banks were vegetated by shrubs and unmowed herbaceous plants, with some adjacent forest canopy. There was no flowing water and only a few shallow pools during the ecological assessment field survey.

Charleston Creek is designated in the PaDEP Chapter 93 Water Quality Standards as a Warm Water Fishery (WWF). The WWF classification provides for maintenance and propagation of fish species and additional flora and fauna that are indigenous to a warm water habitat. These protected uses are in addition to Pennsylvania's standard list of protected uses that include water supply and recreation. The stream is not included in the Pennsylvania Fish and Boat Commission (PFBC) "Listing of Surveyed Streams having Verified Trout Reproduction" nor is it listed as a stocked trout stream in the 1998 Summary of Fishing Regulations and Laws. Charleston Creek also is not part of the Pennsylvania Scenic Rivers System.

A total of 946 fish specimens representing 13 species were collected from four stations in Charleston Creek (see Table 2 in Appendix F). Creek chub was the most common species (36.8% of total), followed by fallfish (23.7%) and central stoneroller (11.2%). The remaining species each comprised under 10 percent of the total, but included two high order predators: chain pickerel and largemouth bass.

Benthic macroinvertebrate collections at the four stations in Charleston Creek yielded a total of 24 families, indicating a "rich" community (see Table 3 in Appendix F). Four families exceeded 10 percent of the total and were the most numerous potential ecological receptors. In decreasing order, these were: net-spinning caddisflies (28.0%), tubeworms (26.3%), sowbugs (15.7%), and midges (10.2%). The remaining families each comprised 5.3 percent or less of the total.



EPT specimens from four EPT families accounted for 30.1 percent of the total, resulting in a high EPT/Chironomidae ratio of 2.95 to 1. However, the presence of only four EPT families indicate that most of the macroinvertebrates present in the study area are fairly pollution tolerant. In addition, *Hydropsychidae* (caddisflies) was the only EPT family that was “numerous”.

Hydropsyches as a general rule are pollution tolerant relative to most other EPT families. Rated on a tolerance scale of 0 to 10, where a higher number indicates greater pollution tolerance, *Hydropsychidae* are given a rating of 4 (US EPA 1989).

Due to lack of flow, fish were absent in the eastern tributary and only 26 specimens of 6 aquatic macroinvertebrate families were collected from several shallow pools. Diving beetles (38.5%), midges (23.1%) and tubeworms (23.1%) were the most abundant taxa. Diving beetles are adapted to lentic (non-flowing) waters and, therefore, it would not be unexpected that this family would be present in the shallow pools remaining in this stream. However, collectively, the other taxa indicate a community responding to environmental stress, almost certainly due to the absence of water. These families are more tolerant of poor water quality and low dissolved oxygen conditions that would be expected in shallow (stagnant) pools. These taxa also are capable of burrowing and can migrate downwards into the stream bed to keep moist during dry periods.

Most of the input zone upstream of the site is vegetated by deciduous forest. The remainder of the input zone has been largely developed, with trees and shrubs largely restricted to narrow bands along sections the stream bank. Typical forest overstory species included black cherry, white ash, black locust, and slippery elm. Also present in some areas were sugar maple, quaking aspen,

Scotch pine, Norway spruce, and boxelder. Multiflora rose, bush honeysuckle, hawthorn, and common blackberry were generally abundant in the understory and along forest edges, while staghorn sumac and various saplings of overstory species were also abundant in localized areas. The ground cover was largely dominated by Dames rocket, but also included white avens, herb robert, musk mallow, stonecrop, and wrinkle-leaved goldenrod. Small areas of old-field vegetation were scattered throughout the input zone and along the stream banks. Old-field species observed included Canada goldenrod, grassleaved goldenrod, giant goldenrod, white heath aster, orange bristle grass, Timothy grass, orchard grass, Queen Anne's Lace, English plantain, and knapweed. See Figure 3 in Appendix F for a general map of plant communities in the study area.

Observed wetlands within the study area were relatively small, with few exceeding 0.5 acre in size. Palustrine emergent wetlands communities commonly occurred on alluvial bars within the stream channel and adjacent to the channel on low terraces. These wetlands were dominated by reed canary grass, along with jewelweed and giant goldenrod in some areas. Also present were panicled aster, boneset, blue vervain, water hemlock, and elderberry. Palustrine forested wetlands also occurred on low terraces adjacent to the stream channel and were only detected in four areas. Species common in these wetlands were slippery elm, willows, Dames rocket, reed canary grass, giant goldenrod, and jewelweed. Boxelder, black locust, white ash, speckled alder, elderberry, sedges, arrow-leaf tearthumb, swamp aster, purple-leaf willow-herb, clearweed, American brooklime, forget-me-not, moneywort, New England aster and boneset also occurred in many of these areas.

Wetlands soils ranged from dark grey (10 YR 4/1) with mottling to black (2.5 Y 2.5/1) at 10 to 12 inches in depth, indicating hydric soil conditions. Many of the palustrine emergent wetlands were



located within the stream channel and most of the emergent and forested wetlands had saturated soils. Additional evidence of wetlands hydrology included vegetation matted in the direction of stream flow, water marks and deposits of waterborne debris above the level of the wetlands, and braided channels through some wetlands.

The U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) maps (see Figure 4 in Appendix F) do not display any of the wetlands identified by field survey. NWI maps are only intended for use as guidance in detecting larger wetlands areas and generally are not of sufficient resolution to detect small wetlands areas such as those in the study area. Charleston Creek was the only aquatic habitat mapped within the study area by the NWI and was classified as a riverine upper perennial water with an unconsolidated bottom and a permanently flooded water regime (R3UBH).

A list of wildlife species observed in the Charleston Creek study area during the stream and input zone surveys is presented as Table 5 in Appendix F. This list is far from comprehensive due to the season, time of day, and limited time available to conduct the survey. Common species of migratory songbirds, reptiles and amphibians that may be present and/or active during other seasons of the year were not detected. Also, common nocturnal species such as raccoons and skunks, which are likely to be present in the study area, were not observed. In addition, common diurnal year-round residents, including the cottontail rabbit, various rodents, and songbirds which are likely to be present, were not encountered during the survey.

Areas of stressed vegetation were not observed during the stream or input zone surveys. Numerous storm water outfalls for parking lots and roads were located along the creek in the



center of the study area from just upstream of the Jackson Street bridge to the Cone Street bridge, located west of the site.

The plant and wildlife management agencies that were contacted all indicated that there are no records of occurrences of threatened, endangered or rare species within the defined ecological assessment study area.



4. NATURE AND EXTENT OF CONTAMINATION

4.1 Potentially Elevated Parameters

The results of first round of field and laboratory analyses were tabulated upon receipt. In order to identify which parameters were to be considered “potentially elevated”, it was first necessary to establish Trigger Levels for each detected parameter. In accordance with Section 3.1.2 of the RFI Workplan, Trigger Levels were established by comparing the Round 1 analytical data from downgradient wells to the higher of the following values:

- Upgradient concentrations.
- Current Drinking Water Maximum Contaminant Levels (MCLs) or U.S. EPA Region III Risk Based Concentrations (RBCs) if no MCL exists for a given parameter.

Based on the groundwater gradients that were determined using the procedures described elsewhere in this report, the well considered to be upgradient for the purposes of establishing Trigger Levels was MW-11. MCLs were obtained from EPA 822-B-96-002, *Drinking Water Regulations and Health Advisories*, dated October 1996. The RBCs were the “tap water” values obtained from EPA’s *Region III Risk-Based Concentration Table*, dated October 1, 1998. Table 3 presents the values that were used in selection of the appropriate Trigger Levels.

It was then necessary to identify which wells were to be used in establishment of the Potentially Elevated Parameters. In accordance with Item 9, Section 3.1.2 of the RFI Workplan, the Potentially Elevated Parameters were determined by comparing the analytical results from monitoring wells near the northwest property boundary to the Trigger Levels. The wells located



near the northern and western property boundaries are MW-7, MW-9, MW-10, MW-12, MW-13 and MW-14. Thus, the Round 1 analytical results for samples from these wells were compared to the Trigger Levels in order to establish the Potentially Elevated Parameter list.

Table 4A presents a summary of the laboratory analytical results from the first round of groundwater sampling during the RFI. This table also presents the Trigger Levels that have been established for each parameter. As shown in Table 4A, no parameters were detected in samples from the wells used to establish Potentially Elevated Parameters in concentrations greater than the Trigger Levels, with one exception. Dissolved arsenic was detected during the first round of groundwater monitoring at a concentration of 0.168 mg/l in MW-13, versus a Trigger Level of 0.05 mg/l. The maximum groundwater concentration from previous groundwater monitoring events that occurred several years ago was 0.0195 mg/l⁷, which is about one-half of the Trigger Level and comparable to the other detectable dissolved arsenic concentration identified during the Round 1 monitoring event (0.026 mg/l at MW-12). Consequently, only dissolved arsenic was considered a Potentially Elevated Parameter for the remainder of the RFI.

Although no dissolved trivalent or hexavalent chromium concentrations were identified in excess of the associated Trigger Level in downgradient monitoring wells during Round 1 monitoring, subsequent groundwater analyses also included dissolved trivalent and hexavalent chromium in accordance with Section 3.1.2 of the RFI Workplan. Testing for standard field parameters (pH, specific conductance, temperature, Eh) was also performed during subsequent monitoring events in the wells that were being sampled.

⁷ Result from MW-4, EPA Site Inspection, September 11, 1990. See Table 3.7, Existing Conditions Report.

4.2 Occurrence and Distribution of Groundwater Contaminants

Tables 4A through 4D present the analytical results from each of the four rounds of groundwater monitoring performed at the facility during the RFI. Table 4E presents a summary of all four sampling rounds to facilitate comparison of results for a given parameter from one round to the next, as well as between monitoring locations. Table 4E only includes those parameters that were monitored during all four sampling events. The data included in these tables supports the following conclusions:

- No significant quality control problems were evident.
- pH values are generally consistent at a given monitoring location during each sampling event.
- Eh (ORP) values are generally positive for all wells, with one exception. Well MW-12 consistently had a negative ORP value (-65 to -35 mV), with a decreasing trend. This is indicative of reducing conditions. The cause for this occurrence is not known, but based on other findings discussed in this report with respect to the RFI objectives, it does not warrant further consideration. It should be noted that Eh was measured on samples that had just been taken using a bailer. This procedure may tend to slightly aerate the sample and therefore cause the results to be slightly higher (i.e., more positive) than an in-situ sample from the aquifer. However, since the procedure was employed consistently, the data is still useful for relative comparison purposes.
- Temperature results appear to depict a seasonal trend and are somewhat reflective of ambient temperatures, which is not unexpected for samples collected using a bailer.
- Conductivity readings were generally consistent at a given monitoring location for each sampling round.



- The analytical results for chromium and arsenic are generally consistent at a given monitoring location for each sampling round (the analytical results for chromium and arsenic are discussed again in more detail in Section 4.3, Statistical Analysis).

The RFI Workplan calls for the development of isoconcentration maps for Potentially Elevated Parameters in groundwater. As described in Section 4.1 of this report, only dissolved arsenic was identified as a Potentially Elevated Parameter in site groundwater. However, during all four monitoring rounds, measurable concentrations of dissolved arsenic were found in no more than two monitoring wells (MW-12 and MW-13). A meaningful isoconcentration map cannot be prepared using only two data points. Therefore, no isoconcentration map was prepared for dissolved arsenic.

Isoconcentration maps were prepared for dissolved hexavalent chromium, even though dissolved hexavalent chromium was not identified as a Potentially Elevated Parameter. The isoconcentration contour lines were developed using the same software and methodology used to develop groundwater contours, as described previously in this report. However, rather than use the actual concentration results, the contours were plotted using the logarithm of the concentration values. This was performed based on the fact that the spatial distribution of environmental data such as this is frequently lognormal, and this method resulted in a more representative set of isoconcentration contours. The lognormal distribution of dissolved hexavalent chromium concentration data is verified and illustrated in Figure 8 of Appendix 8.

The dissolved hexavalent chromium isoconcentration maps prepared using each round of monitoring data are presented in Figures 4A through 4D. These maps indicate the presence of a small, static area of chromium-impacted groundwater, which extends in a northwesterly direction

away from the former dry well area. This direction is consistent with the measured horizontal groundwater gradient in the shallow overburden aquifer, as discussed in Section 3.3 of this report. It should be noted that the maps indicate that the impacted area remains well within the facility boundaries. Also, the maps indicate that there is no significant change in the shape or extent of the impacted area during the RFI monitoring period.

Table 5 presents a summary of historical hexavalent chromium data and compares it to the sampling results from the four rounds of monitoring during the RFI. This comparison illustrates that the dissolved hexavalent chromium concentration detected during the RFI are generally comparable to the concentrations reported during groundwater monitoring events that occurred 9 to 11 years ago. Thus, the historical data and the data collected during the RFI clearly indicate that the impacted area is not migrating. The fate and transport of hexavalent chromium in site groundwater is discussed again in Section 5 of this report.

4.3 Statistical Analysis

As required in Section 3.2.5 of the RFI Workplan, statistical analyses were performed on the groundwater quality data obtained from the four rounds of monitoring during the RFI. The purpose of the statistical evaluation was to determine the limits within which 95 percent of the groundwater contaminant concentrations could be expected to occur. As specified in Section 3.1.2 of the RFI Workplan, the parameters subjected to this statistical analysis were those included on the Potentially Elevated Parameter list (dissolved arsenic), although the statistical analysis was also performed for hexavalent chromium.

To establish these 95 percent limits, the Student's t test was selected as the statistical method. This test is widely used to establish tolerance limits for normally-distributed data. However, before the Student's t test could be performed, it was first necessary to verify that the collected data sets were in fact normally distributed over time. To do this, the coefficient-of-variation test was applied. The coefficient-of-variation (CV) is calculated for a given set of data as follows:

$$CV = S / \bar{X}$$

where: \underline{S} = sample standard deviation
 \underline{X} = sample arithmetic mean

If the calculated CV value is less than 1.00, it indicated that the data set does vary normally. Should the CV value exceed 1.00, it indicates that the data set is not normally distributed and must first be transformed log normally and then rechecked for normality in the manner described above before the Student's t test can be applied.

Once the data were checked for normality, the Student's t test was applied to each data set to calculate the upper 95 percent tolerance limits as follows:

$$95\% \text{ limit} = \bar{X} \pm (2.353 \times S)$$

where: 2.353 is a coefficient based on 3 degrees of freedom⁸
(i.e., number of data points minus 1)

Note: that for all statistical calculations, one-half of the Method Detection Limit (MDL) was used

⁸ Taken from Table IV of R. A. Fisher, "Statistical Methods for Research Workers".



where the concentration was reported as non-detectable, and “J” qualifiers⁹, where reported, were ignored. Furthermore, the lower 95 percent tolerance limit was not calculated, since it is not critical to know how low of a concentration can be expected for the subject parameters (i.e., the test was performed as a single-tailed test). Where the standard deviation and mean were both less than the MDL, or where four data points did not exist, no meaningful statistical limits could be calculated (i.e., standard deviation could not be calculated or was zero).

The results of these statistical analyses are presented in Table 6. The following conclusions may be drawn from the data:

- All subject data sets varied normally. Therefore, no lognormal transformations were required.
- Based on the discussion presented above, statistical limits were calculated for the following wells and parameters:

Hexavalent chromium:	MW-2, MW-9
Dissolved arsenic:	MW-12, MW-13

- The observed on-site concentrations of chromium and arsenic are likely not the result of off-site conditions or events.

⁹ A “J” qualifier indicated that the parameter was detected at a concentration greater than the Method Detection Limit but less than the Practical Quantitation Limit.



The calculated 95 percent limits shown in Table 6 have been used in the fate and transport calculations that are discussed in Section 5 of this report.



5. CONTAMINANT FATE AND TRANSPORT

Based on the findings of the RFI discussed in the previous sections of this report, there were two groundwater contaminants of interest that warranted further evaluation: dissolved arsenic and dissolved hexavalent chromium. To assess the potential impact these metals may have on public health or the environment, the performance of a risk assessment was necessary. However, before a risk assessment could be performed, it was first necessary to model how these two groundwater contaminants would be expected to move through the subsurface environment to potential receptors; this modeling was required since no data collected during this RFI, or previously, indicated that the contaminants are currently present beyond the facility boundary in concentration in excess of the Trigger Levels or other relevant health-based criteria. Such modeling is referred to as fate and transport modeling.

Recent and historical ground water data were reviewed to determine whether contaminants detected in on-site wells are likely to impact the water quality at off-site domestic wells and in Charleston Creek. Two tasks were undertaken during the contaminant fate and transport evaluation:

- Task 1: Model the ground water flow in the overburden and bedrock aquifers in the vicinity of the site, and determine whether dissolved arsenic and/or hexavalent chromium detected in groundwater beneath the site would be expected to impact off-site domestic wells.

Task 2: Model the on-site overburden aquifer discharge to Charleston Creek to assess whether dissolved contaminants detected in the overburden aquifer would be expected to impact the water quality in the creek.

The overburden/bedrock aquifer ground water flow model (Task 1) is presented in Section 5.1; contaminant fate and transport in the overburden aquifer (Task 2) is discussed in Section 5.2.

5.1 Bedrock Groundwater Flow Model

A groundwater flow model was used to determine whether contaminants detected in the shallow overburden aquifer beneath the site are likely to migrate through the bedrock beneath Charleston Creek and be captured by pumping at domestic wells located northwest of the site. The domestic wells (locations 39, 40, 41 and X0943) identified on Figure 7 are located at distances that range from 1,200 to 1,900 feet from the site. Note that for the purposes of this modeling, it was conservatively assumed that domestic wells exist at locations 39, 40 and 41 - these are actually properties that have a water supply waiver and only suggest the presence of a domestic well.

The model was constructed using Flowpath II Version 1.0, a two-dimensional, finite-difference ground-water flow model (Waterloo Hydrogeologic, of Ontario, Canada). Conceptually, the model was set up as a slab of unit thickness intended to represent a vertical section through the overburden and bedrock aquifers in the vicinity of the site. This approach was used to simplify the hydrogeologic problem, yet determine whether pumping at domestic wells located northwest of the site and Charleston Creek is likely to capture contaminated ground water from the overburden aquifer at the site.



A detailed discussion regarding the model input parameters and various model runs that were performed is presented in Appendix H. As described in that discussion, conservative assumptions were made where certain input variables were not defined. Despite the extremely conservative nature of the model, the results indicate the following:

- None of the water from the overburden aquifer at the site flows into the bedrock aquifer and passes below Charleston Creek. Instead, such groundwater is shown to discharge into Charleston Creek, thereby confirming the function of the creek as a hydraulic boundary for overburden water.
- No groundwater recharging the site and encountering the impacted area could be captured by any of the wells identified. Although water within the bedrock aquifer below the site at depths of 150 to 250 feet is shown to migrate below Charleston Creek and flow to the known or assumed locations of domestic wells across the creek, this water represents recharge to the bedrock that originates at distances approximately 1,400 to 1,500 feet south of the site (and therefore not impacted by site operations).

5.2 Fate and Transport

An analysis was performed to determine whether the dissolved arsenic and hexavalent chromium detected in the shallow overburden aquifer at the site are impacting the water quality of Charleston Creek. Fate and transport issues associated with each contaminant are discussed separately below.



5.2.1 Hexavalent Chromium

The source of the hexavalent chromium detected in the overburden aquifer beneath the site is the former dry well located immediately adjacent to the southern wall of the former Furnace Building. Reportedly, chromium-plating rinse waters were routinely discharged to the dry well by the previous owner (Corning). Exact dates during which the dry well was used by Corning are not known, but the practice ceased prior to 1980. Presumably, the hexavalent chromium source in the subsurface was well established by the time the use of the dry well was discontinued, and the dissolved metal was impacting the groundwater quality at the site at that time. Removal of the source material (impacted soils) subsequently occurred (see Section 1.2.2), leaving only the residual impacted ground water.

As stated in Section 4, hexavalent chromium concentrations detected in on-site wells during four rounds of groundwater monitoring during the RFI have remained relatively constant. At MW-2, located approximately 15 feet from the former dry well, hexavalent chromium concentrations have ranged from 3.09 to 4.72 mg/l (see Tables 4A through 4D). As shown in Table 5, previous sampling at the well during July 1988, October 1989, and September 1990 detected 4.2, 4.0 and 6.2 mg/l, respectively. The 10 mg/l detected in the December 1987 sample does not appear to have been representative of the water quality of the shallow aquifer, and was probably caused by the disturbance to the subsurface during soil remedial activities that took place at that time.

Well MW-6, located approximately 150 feet downgradient of the former dry well area, monitors the central portion of the dissolved hexavalent chromium plume detected at the site. Hexavalent chromium concentrations at this well ranged from 0.845 mg/l to 1.56 mg/l during the RFI (Table



4A through 4D). Hexavalent chromium was reported at a comparable concentration of 0.96 mg/l in 1989.

At downgradient well MW-9, located approximately 350 feet downgradient of the former dry well, hexavalent chromium concentrations were relatively constant during the four groundwater sampling events during the RFI and ranged from 0.038 mg/l to 0.055 mg/l.

During October 1998, sampling performed at well MW-12 (located roughly 500 feet downgradient of the former dry well) did not detect any hexavalent chromium, thus delineating the horizontal extent of the dissolved plume. The creek is located approximately 550 feet from the former dry well, along a line perpendicular to the plotted groundwater contours.

A groundwater seepage velocity of 3.9 ft/d is calculated for the overburden aquifer at the Site (using the hydraulic conductivity value of 23 ft/d, a hydraulic gradient as steep as 0.017, and an assumed effective porosity of 0.1). Since over 6,500 days have passed since 1980, ground water beneath the site could theoretically have traveled more than 25,000 feet (with no effects from any retardation, dispersion, etc.). However, the relatively constant hexavalent chromium concentrations detected at MW-2 and MW-9 during the four rounds of groundwater monitoring support the conclusion that the dissolved hexavalent chromium impacted area at the site is old and stable. The groundwater data clearly demonstrates that geochemical processes are having a major impact on the fate and transport of the hexavalent chromium at the site. It is well established that oxidation-reduction processes play a major role in affecting the mobility of chromium because it is relatively mobile as hexavalent chromium and immobile in its trivalent form. Under typical subsurface conditions with an Eh of less than +250 mV, hexavalent chromium will be reduced to

trivalent chromium, which will precipitate as the insoluble mineral $\text{Cr}(\text{OH})_3$ or $(\text{Fe,Cr})(\text{OH})_3$ (Deutsch, W.J. 1997). Eh measurements at the site confirm that the favorable Eh conditions are present in the subsurface at the site (see Section 4.2).

The reduction rate for hexavalent chromium will also depend on the pH of the environment and on the presence of reductants such as organic matter or clays. The precipitation of chromium hydroxides is favored by neutral to slightly alkaline pH conditions, such as those generally noted during the four groundwater monitoring events (see Section 4.2). Based on the limited distance that the hexavalent chromium has migrated during the decades it has been in existence, the oxidizing capacity of the chromium contamination has not exceeded the reducing capacity of the subsurface environment.

Estimating the half-life of the hexavalent chromium at the site is complex, since many undefined variables need to be evaluated. However, a plot of the log of the hexavalent chromium concentration versus the distance from the former dry well using data from MW-2, MW-6 and MW-9 for the October 1998 and August 1999 sampling rounds (the only rounds when all three wells were sampled) reveals a straight-line relation that is typical of a first-order reaction (see Figure 8 in Appendix H). The graph illustrates that subsurface conditions are acting to remove dissolved hexavalent chromium from the groundwater beneath the site, presumably through reduction and hydroxide precipitation. It also demonstrates that hexavalent chromium concentrations drop to levels below the Method Detection Limit of 0.003 mg/l prior to reaching Charleston Creek.



The absence of an ongoing release, the time since the initial release, the seepage velocity of groundwater in the overburden, and the laboratory data from on-site wells all combine to indicate that hexavalent chromium in ground water beneath the site will not impact the water quality of Charleston Creek in the future.

5.2.2 Arsenic

The following calculations were performed to estimate potential loading of dissolved arsenic to Charleston Creek due to groundwater discharging from the shallow overburden aquifer in the vicinity of wells MW-13 and MW-12. As shown in Table 4E, dissolved arsenic was detected at wells MW-12 and MW-13, which are located near the perimeter of the site and approximately 70 and 110 feet from Charleston Creek, respectively. The arsenic concentrations detected at MW-13 during the four sampling rounds ranged from 0.039 mg/l to 0.168 mg/l. At MW-12, the reported dissolved arsenic concentrations ranged from less than 0.007 mg/l to 0.026 mg/l. There are no wells located between MW-12 and MW-13 and the creek.

To determine the potential impact of groundwater containing dissolved arsenic discharging to Charleston Creek, a diffuse flow of contaminated groundwater calculation was completed (PaDEP 1997). This calculation assumes the total contaminant mass load into the stream is constant and the diffuse flow into the cross-sectional area of the stream is uniformly mixed. The calculation is performed using the following equation:



$$C_{sw} = (Q_{gw} \times C_{gw}) / Q_{sw}$$

where:

C_{sw} = resultant concentration in the surface water stream (mg/l)

Q_{gw} = groundwater discharge flow rate from cross-sectional area of impacted area into the stream (gpm). This may be estimated as kiA where:

k = hydraulic conductivity (ft/day)

i = hydraulic gradient (ft/ft)

A = cross-sectional area of impacted area at point of stream intersection (ft²)

C_{gw} = area-weighted average concentration of the parameter in groundwater (mg/l)

Q_{sw} = surface water flow rate upstream of the impacted area during low-flow conditions (gpm)

The cross-sectional area of impacted area at point of stream intersection was constructed using three zones. Approximately 200 feet separate MW-13 from the projection of MW-12 onto a plane perpendicular to groundwater flow. Therefore, a 200-foot wide central portion centered on MW-13 (Zone 1) was created where the most elevated arsenic concentrations are present. The central portion of the area is bounded on each side by two 70-foot wide portions where less elevated arsenic concentrations are present (Zones 2 and 3). Refer to Figure 9 in Appendix H for an illustration of these zones. This results in a total width of the impacted area of 480 feet.

The boring logs for MW-12 and MW-13 indicate that the screened portions of the well intersect a saturated coarse fill layer that is approximately 4 feet thick (see Appendix B). Below the fill, the screens intersect a fine silt horizon where the groundwater flow velocity will be significantly lower



than in the coarser fill. As a result, the total cross-sectional area of impacted area at point of stream intersection was 480 feet wide by 4 feet thick, or 1,920 square feet.

The overburden aquifer values derived in this RFI for hydraulic (23 ft/d) and hydraulic gradient (0.017 ft/ft) were used in the equation to calculate the groundwater discharge flow rate from cross-sectional area of impacted area into the stream.

The area-weighted average concentration of the parameter in groundwater was then calculated. Zone 1 was assumed to contain 0.204 mg/l dissolved arsenic, which was the upper 95% value determined statistically from the quarterly sampling data at MW-13 (see Table 6). The arsenic concentration of Zones 2 and 3 were determined using the concentration gradient that exists between well MW-12 and MW-13. A concentration gradient of 0.00084 mg/l per foot was determined, again using the statistically-derived 95% upper limit of 0.204 mg/l and 0.037 mg/l for wells MW-12 and MW-13, respectively. Therefore, at 100 feet sidegradient of well MW-13, the arsenic concentration is approximately 0.120 mg/l; this concentration was assumed to be present throughout the 70-foot wide Zone 2 portions of the aquifer on each side of the central Zone 1.

The same calculation was repeated for a distance of 170 feet side gradient of well MW-13, and an arsenic concentration of 0.061 mg/l was determined. This concentration was assumed to be present throughout the two 70-foot wide Zone 3 portions of the aquifer.

A stream flow rate of 215 gpm was used for Charleston Creek. This is based on historical flow in the creek as measured at the Parshall flume along the east side of the site (see Appendix I), plus the typical treated plant wastewater discharge measured at their NPDES Outfall 001. The creek



flow value was determined from the review of historical flow data for the creek that shows that there are frequent periods of three days or more when flow is as low as 180,000 gpd (125 gpm); there are also periods when the flow is well in excess of 1,875 gpm. Wellsboro Borough personnel indicate that they strive to keep at least 300,000 to 600,000 gpd (200 to 400 gpm) flowing through the flume by regulating discharges from Hamilton Lake and into Charleston Creek. However, since Hamilton Lake is part of the Borough's water supply system, the flow through the flume may occasionally be slightly less than desired in order to maintain sufficient level in the lake for water supply purposes. To be conservative in the stream loading calculations, a flow of 125 gpm was used as the flow in the creek.

The average monthly discharge from the plant at Outfall 001 is 92 gpm. This outfall flows on essentially a continuous basis; flow is only stopped during complete plant shutdowns which are very rare. The outfall location is upstream of where arsenic in ground water is assumed (for the purposes of this calculation) to discharge to the creek. Therefore, a combined flow of 215 gpm (125 plus 90 gpm) was used to calculate arsenic concentrations in the creek after groundwater mixes with the stream flow at low flow conditions.

The stream loading calculations are summarized on Table 2 in Appendix H. As shown in this table, the diffuse flow calculation results in an average predicted arsenic concentration of 0.138 mg/l in groundwater discharging to the stream, and an arsenic concentration of 0.00245 mg/l in Charleston Creek. This calculation demonstrates compliance with the applicable ambient water quality criteria (WQC) of 0.190 mg/l. This approach is conservative since it uses the calculated 95% limits and assumes that no reduction in these concentrations occurs prior to groundwater discharging to the creek.



6. HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

As stated in Section 3.7, no complete exposure pathways from site groundwater to potential human receptors were identified. Therefore, no human health risk assessment was needed as part of this RFI. As discussed in the previous section, arsenic contributions from the site to Charleston Creek are well below the applicable WQC. However, as a conservative step, an ecological risk assessment was performed.

The ecological risk assessment was conducted in accordance with the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997). The referenced guidance document outlines an eight-step process for evaluating ecological risk. The initial two steps of the process define the screening process, in which chemicals known or suspected to pose unacceptable risk are identified and screened using conservative benchmarks. If the screening-level assessment identifies a potential for unacceptable risk, the process continues using assumptions and data that are more specific to the site under evaluation.

This section of the RFI report addresses Steps 1 and 2 of the eight-step process. Section 6.1 presents the screening level-problem formulation (Step 1). This step includes a description of the environmental setting; identification of known and suspected contaminants; discussion of the fate and transport characteristics and toxicity of the suspected contaminants; identification of the potentially complete exposure pathways, assessment endpoints for the screening-level assessment, and potential ecological receptors; and selection of screening-level benchmarks. Section 6.2 of this document presents the results of the screening-level exposure assessment (Step 2). This step



includes estimation of exposure parameters and exposure concentrations; the screening-level evaluation; and conclusions of screening-level assessment. Section 6.3 of this document presents a discussion of the uncertainties associated with the screening-level assessment.

6.1 Screening-Level Problem Formulation

6.1.1 Environmental Setting

The environmental setting for the site as it pertains to the ecological risk assessment was discussed in Section 2.7 (Ecological Assessment) and Section 3 (Physical Characteristics of the Study Area) of this report.

6.1.2 Known and Suspected Contaminants

The known and suspected contaminants are discussed in Section 1.2 (Site Background) and Section 4 (Nature and Extent of Contamination) of this report. Both arsenic and hexavalent chromium were considered to be contaminants of potential ecological concern in this ecological risk assessment.

It should be noted that there are no known or suspected ongoing releases of either arsenic or hexavalent chromium on the site. Arsenic is not currently used in the manufacturing processes or for other ancillary purposes at the site. Furthermore, operational records indicate that arsenic has not been used in the manufacturing processes since at least 1981 while the plant was owned and operated by OSRAM or its predecessor, GTE. The use of

the chromium dry well has been discontinued since at least 1980, and impacted soils in the vicinity of the dry well were excavated and removed in 1989.

6.1.3 Contaminant Fate and Transport

Section 5 of this report discusses the fate and transport of identified groundwater contaminants (arsenic and hexavalent chromium). The fate and transport of each of these compounds, as it pertains to the assessment of risk, is discussed in more detail in the following subsections of this report.

6.1.3.1 Arsenic

The elemental form of arsenic does not normally occur in nature. Arsenic occurs mostly as the arsenides of true metals or as pyrites. It is generally recovered as a by-product from the processing of other ores (e.g., copper, lead, zinc and tin). Upon smelting of these ores, arsenic is oxidized and liberated in flue dust, chiefly as arsenic trioxide, but it also forms tetraoxides and pentoxides. Hence, arsenic may have valence states of +3, +4 and +5, but the +3 and +5 forms predominate. Arsenic is used in metallurgy to increase hardening and heat resistance of glassware and ceramics, in tanning processes, in dye manufacturing, and in chemical industries. The major uses of arsenic, however, have been for pesticides (insects, weeds, fungi) and as a wood preservative.

Arsenic in the atmosphere exists as particulate matter, mostly less than 2 μm in diameter. These particles are transported by wind and air currents until they are returned to earth by wet or dry deposition. The residence time of particulate-bound arsenic depends on particle

size and meteorological conditions. A typical residence time is about 9 days (ATSDR 1992). The fate of arsenic in water depends on its chemical form (oxidation state and counter ion) and interactions with other materials present. In general, the trivalent forms tend to predominate in less oxygenated water and sediments, while the pentavalent form tends to predominate in surface waters (Eisler 1988). The trivalent form tends to be more soluble than the pentavalent form (Eisler 1988). However, both forms may adsorb to sediments, especially clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material. Under most conditions, co-precipitation or sorption of arsenic with hydrous iron oxides is the predominant process in the removal of dissolved arsenic from the water column (CCME 1993). Sediment-bound arsenic may be released back into the water column by chemical or biological interconversions of arsenic species. There is no evidence that photolysis and volatilization are important removal mechanisms of arsenic in the aquatic environment.

Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and lower invertebrates. Bioconcentration factors measured in freshwater invertebrates and fish for several arsenic compounds range from 1 to 17 L/kg. Biomagnification in aquatic food chains does not appear to be significant (ATSDR 1992)

6.1.3.2 Chromium

Chromium may occur in variable forms, but the most common are trivalent chromium and hexavalent chromium (Eisler 1986). Trivalent chromium occurs naturally in the environment (i.e., in the earth's crust, plants, soils) and is also used as pigments in the

chemical industry and as an agent in leather tanning. Hexavalent chromium, on the other hand, does not occur naturally in the environment. Hexavalent chromium is widely used in the chemical industry as pigments, wood preservatives, and in pickling and plating in the process of metal finishing. Smaller amounts of either chromium form are used in drilling muds, water treatment as rust and corrosion inhibitors, chemical manufacturing, toners for copying machines, and in magnetic tapes.

Chromium in the atmosphere usually exists as particulate matter. Chromium particles are transported by wind and air currents until they are returned to earth by dry or wet deposition. The residence time of particulate-bound chromium depends on particle size and meteorological conditions. A typical residence time is about 10 days.

The fate of chromium in aquatic environments depends on the oxidation state, counter ion, and interactions with other materials. However, the majority of chromium in water will ultimately be deposited in sediment as it tends to sorb strongly to clays and organic matter. Soluble chromium is predominantly present as trivalent and hexavalent chromium complexes. Trivalent chromium occurs mostly adsorbed to suspended clays, organics, or iron oxides present in the water. Hexavalent chromium in water will eventually be reduced to trivalent chromium and then sorb to these materials.

Chromium in soil is not very mobile due to its strong sorption to clay and to organic matter. Soluble hexavalent chromium in soil is expected to convert to trivalent chromium, which is much less soluble. Chromium in soils, both soluble and particulate forms, may be transported to surface water via surface runoff. Depending on pH, soluble and insoluble

trivalent and hexavalent chromium complexes may be leached from soils and transported to groundwater. However, under neutral to alkaline pH conditions, the chromium will tend to remain in soil as a hydroxide precipitate.

The bioconcentration factor (BCF) for hexavalent chromium in rainbow trout is ± 1 L/kg. In bottom feeders, the BCF values for trivalent and hexavalent chromium ranges from 192 to 867 L/kg. Biomagnification in aquatic food chains does not appear to be significant. Chromium also has low mobility in plants. Most of the chromium taken up by plants growing in soils having measurable concentrations of chromium is retained in the roots. Translocation to the above ground part of edible plants is minimal. Therefore, bioaccumulation from soil to above ground parts in plants is unlikely. There is also no indication of biomagnification of chromium within the terrestrial food web.

6.1.4 Toxicity

6.1.4.1 Arsenic

In the aquatic environment, a concentration of trivalent arsenic of 13,300 $\mu\text{g/l}$ has induced an acute toxic response in fish (fingerling rainbow trout). The lowest known acutely toxic concentration of pentavalent arsenic for fish (rainbow trout) is 10,800 $\mu\text{g/l}$ (CCME 1993). Invertebrates are generally more sensitive to arsenic than fish. Acute toxicity of trivalent arsenic has been documented at concentrations of 812 $\mu\text{g/l}$ for a cladoceran and 874 $\mu\text{g/l}$ for an amphipod. Pennsylvania has chronic water quality standard for protection of aquatic life of 190 $\mu\text{g/l}$ for arsenic. According to Eisler (1988), there is consensus that the

trivalent form is more toxic than the pentavalent form. However, EPA (1999) suggests that toxicities of both forms of arsenic to aquatic life are comparable, and has promulgated a water quality criterion for total arsenic based on toxicity to the trivalent form.

6.1.4.2 Chromium

In the aquatic environment, the toxicities of chromium vary widely among species as a function of temperature, pH, valence state, and synergistic or antagonistic effects, especially that of hardness for the trivalent form. In general, hexavalent chromium is more toxic to aquatic life than trivalent chromium. This is reflected in the water quality criteria for chromium. At a hardness of 100, hexavalent chromium has a chronic water quality criterion of 11 $\mu\text{g/l}$, compared to 74 $\mu\text{g/l}$ for the trivalent form (EPA 1999). Fish are relatively tolerant of chromium. Invertebrates and phytoplankton are more sensitive. The concentration of hexavalent chromium that is reported to be toxic to the early life stages of rainbow trout and brook trout is 264.6 $\mu\text{g/l}$. Similar tests with less sensitive fathead minnows induced adverse effects at much higher concentrations. Invertebrates (i.e., daphnids) are more sensitive; chronic tests with 5 species of daphnids yielded toxicities at concentrations less than 2.5 $\mu\text{g/l}$ to 40 $\mu\text{g/l}$ (CCME 1992).

Acute toxic effects (LC_{50} in 96-hour tests) of trivalent chromium to mayflies (*Ephemerella subvaria*) have occurred at 2,221 $\mu\text{g/l}$. Phytoplankton have been shown to be more sensitive to chromium than fish. Toxic concentrations of hexavalent chromium for bluegreen algae (*Microcystis aeruginosa*) range upward from 2 $\mu\text{g/l}$ (Suter and Tsao 1996).



6.1.5 Potentially Complete Exposure Pathways and Receptors

Since the identified contaminants are associated with groundwater in the shallow overburden aquifer beneath this industrialized site, exposure of ecological receptors to impacted soils is an incomplete pathway. Similarly, exposure to contaminants transported to Charleston Creek via overland flow from the site is also an incomplete pathway. Potentially complete exposure pathways are therefore limited to those associated with groundwater flow.

The potentially complete pathways are: 1) exposure of biota to the surface water of Charleston Creek at the points of groundwater discharge, and 2) exposure of biota inhabiting the sediments of Charleston Creek. The primary source of hydrology for the wetlands appears to be overflow from Charleston Creek during flood events. Therefore, ecological receptors utilizing the palustrine-forested wetlands are not exposed to contaminants originating from the site.

Because arsenic and chromium does not biomagnify significantly in the food web, the exposure pathway for mammalian and avian piscivores that forage in Charleston Creek is incomplete.

In summary, the potentially-complete exposure pathways are limited to Charleston Creek. Accordingly, the assessment endpoints are associated with the aquatic life that inhabits



Charleston Creek. For this ecological risk assessment, the following assessment endpoints were selected:

- Diversity of aquatic organisms inhabiting the water column of Charleston Creek.
- Diversity of benthic community inhabiting Charleston Creek and its sediments.

Individual ecological receptors are not considered in a screening-level assessment. Screening-level benchmarks that are protective of the most sensitive species of aquatic life (water column and benthos) are readily available. These benchmarks are compatible with the identified assessment endpoints.

6.1.6 Screening-Level Ecological Effects Evaluation

Risk to organisms exposed to arsenic and hexavalent chromium in the water column were evaluated by comparing the estimated concentrations in groundwater at the point of discharge to the appropriate screening benchmark for surface waters. Risk to benthic organisms inhabiting the sediments of Charleston Creek were also assessed by comparing estimated groundwater concentrations at the point of discharge to screening benchmarks for surface water. Benchmarks for sediments used in risk assessments are typically derived using the EPA equilibrium partitioning (EqP) method. Benchmarks based on the EqP method are essentially surface water criteria converted to bulk sediment concentrations based on partitioning theory (EPA 1993; 1994). Criteria for bulk sediments are generally preferred because it is easier to measure chemical concentrations in bulk sediments than in the pore water of the sediments. For this ecological risk assessment, groundwater

concentrations provide a direct, albeit conservative, estimate of concentrations in sediment pore water. The use of groundwater concentrations to evaluate risk to benthic organisms is based on the following assumptions:

- ambient water quality criteria are applicable to benthic organisms;
- exposure to toxic chemicals is through pore water concentrations; and
- all of the sediment pore water comes from groundwater discharge (i.e., no dilution by overlying surface water).

The first two assumptions are the basis for the EPA's equilibrium partitioning methodology for sediment quality criteria (EPA 1993; 1994). The third assumption is very conservative, as there is likely to be considerable dilution of the sediment pore water with overlying surface water.

For arsenic, Pennsylvania has a chronic water quality criterion of 190 $\mu\text{g/l}$ for the protection of aquatic life. Oak Ridge National Laboratory (ORNL) also identifies 190 $\mu\text{g/l}$ as the ecological screening value (ESV) for trivalent arsenic (Sutter and Tsao 1996). The USEPA has a chronic water quality criterion of 150 $\mu\text{g/l}$ for total arsenic. For this ecological risk assessment, the lower USEPA concentration of 150 $\mu\text{g/l}$ was used as the ESV for surface water and sediment pore water.

Chromium associated with the site groundwater occurs primary in the hexavalent form. The EPA ambient water quality criterion for hexavalent chromium is 11 $\mu\text{g/l}$. ORNL also

identifies 11 $\mu\text{g/l}$ as the ESV for hexavalent chromium (Suter and Tsao 1996). Accordingly, 11 $\mu\text{g/l}$ was used as the ESV for surface water and sediment pore water.

6.2 Screening-Level Exposure Assessment

6.2.1 Exposure Parameters and Concentrations

In the screening-level exposure assessment, conservative exposure parameters, exposure concentrations, and benchmarks are used. By using the most conservative assumptions, the probability of not identifying actual risk (i.e., false negative) is essentially zero. The predicted concentrations of arsenic and hexavalent chromium in groundwater at the point of discharge into Charleston Creek are used as the exposure point concentration for both biota in both the water column and sediments (pore water in sediments is the media that poses potential risk to benthic organisms, not the sediments themselves). Use of groundwater concentrations is very conservative because dilution of groundwater entering Charleston Creek will undoubtedly occur.

Using the fate and transport modeling discussed in Section 5 of this report, the concentration of arsenic in groundwater at the point of discharge into Charleston Creek was estimated to be 138 $\mu\text{g/l}$. Similarly, the concentration of hexavalent chromium was estimated to reach a concentration of less than the method detection limit of 3 $\mu\text{g/l}$ prior to discharging into Charleston Creek. Consistent with the screening-level assessment, conservative assumptions were used in the models. For example, the 95 percent upper confidence level (UCL) of the mean was calculated for arsenic based on data from

quarterly groundwater monitoring events. Although the 95 percent UCL exceeded the maximum concentration detected, the UCL was used in the model.

6.2.2 Screening-Level Evaluation

The concentration of arsenic in groundwater at the point of discharge (138 $\mu\text{g/l}$) does not exceed the ESV of 150 $\mu\text{g/l}$. Accordingly, arsenic can be eliminated as a contaminant of potential ecological concern.

The concentration of hexavalent chromium at the point of discharge into Charleston Creek is estimated to be less than the method detection limit of 3 $\mu\text{g/l}$, which is well below the ESV of 11 $\mu\text{g/l}$. Accordingly, hexavalent chromium can also be eliminated as a contaminant of potential ecological concern.

The conservatism of screening-level evaluation must be emphasized. The concentration of arsenic in groundwater at the point of discharge represents a worst-case exposure scenario for aquatic life in the creek, specifically benthos at points of groundwater discharge to the creek. Taking dilution into account, the concentration of arsenic in surface water at low flow in Charleston Creek is estimated to be 2.45 $\mu\text{g/l}$ (Section 5.2.2), which is two orders of magnitude below the ESV. Furthermore, dilution is likely to be appreciable for coarser sediments (e.g., sand and gravel), which are characteristic of Charleston Creek.

Many of the infaunal benthos that inhabit finer sediments, like the chironomids, physically aerate their subsurface burrows with overlying surface water. Other infaunal species, such

as bivalves, pump surface water from the surface across their gills. The oligochaetes feed head down in the sediments, but they tend to leave their tails and gills above the sediment surface. In all of these cases, surface water, not sediment pore water, may pose the primary exposure to even the true infauna in this creek. It is also important to recognize that infaunal benthos are generally less sensitive to metals than water column species (EPA 1993). Data on arsenic toxicity to freshwater infauna are limited. Those data available suggest that chironomids and oligochaetes, two of the four common taxa identified in the ecological assessment (Section 3.7), are rather insensitive to arsenic toxicity. Based on four studies obtained from the AQUIRE database, the lowest concentration causing acute toxicity in chironomids and oligochaetes is 36,700 $\mu\text{g/l}$, which is two orders of magnitude higher than the maximum concentration detected in groundwater.

Ecological risk assessment is a multi-step process. The process proceeds from the conservative screening-level assessment to the baseline assessment only if the potential for unacceptable ecological risk remains. In the screening-level assessment completed for the site, arsenic can be eliminated as a contaminant of potential ecological concern. Because the screening-level assessment identified no potential for unacceptable ecological risk, there is no need to advance to a baseline ecological risk assessment.

6.3 Uncertainty in Screening-Level Evaluations

A high degree of uncertainty is inherent in screening-level ecological risk assessments. Worst-case assumptions, maximum exposure concentrations, and benchmarks protective of the most sensitive receptors are used to avoid underestimating the potential for ecological



risk. All of the known uncertainty in the screening-level assessment performed as part of this RFI is biased in favor of identifying risk. Major sources of uncertainty in this ecological risk assessment include:

- The use of conservative assumptions in the modeling of fate and transport of arsenic and hexavalent chromium in groundwater flow from the site and discharging to Charleston Creek.
- The use of the concentration of arsenic in groundwater at the point of discharge as the exposure concentration for aquatic life in Charleston Creek. Consideration of dilution by Charleston Creek would more accurately reflect exposure concentrations for aquatic organisms inhabiting the water column and sediments.
- Use of water quality criteria, which are intentionally conservative in order to be protective of the most sensitive species, as screening benchmarks. As identified in the ecological assessment, the aquatic community of Charleston Creek is relatively pollution tolerant.

Therefore, the actual risk posed to the inhabitants of Charleston Creek is unknown but has been assessed very conservatively.



7. SUMMARY AND CONCLUSIONS

Based on the information and findings presented herein, the following conclusions have been drawn with respect to the stated RFI Objectives:

1. The groundwater monitoring network at the site is adequate to address the RFI objectives.
2. The concentrations of dissolved hexavalent chromium in groundwater are stable and consistent with previous data, and indicate that hexavalent chromium has not migrated offsite.
3. Dissolved arsenic was the only parameter from the Abbreviated Appendix VIII list that was identified at a concentration in excess of the Trigger Level. This occurred at only one well (MW-13).
4. Based on the conservative fate and transport modeling that was performed during the RFI for dissolved hexavalent chromium and dissolved arsenic, contaminated groundwater migration is controlled at the facility.
5. There are no viable, complete exposure pathways for potential human exposure to the dissolved hexavalent chromium or dissolved arsenic identified in site groundwater. The ecological risk assessment has demonstrated that there is not a significant risk to the Charleston Creek ecosystem from discharging groundwater with identified concentrations



of dissolved arsenic. Therefore, human health and ecological exposure is controlled at the facility.

6. The facility has completed its obligations under the RCRA Corrective Action program.



REFERENCES

RCRA Facility Investigation, Task I: Existing Conditions Report. SE Technologies. January 25, 1994.

RCRA Facility Investigation, Task III: RFI Workplan. SE Technologies. January 24, 1994. Revised by Killam Associates. June 2, 1998.

Interim RFI Summary Report, OSRAM Sylvania Products Inc., Wellsboro, Pennsylvania. Killam Associates. February 1999.

Driscoll, Fletcher G., 1986, Groundwater and Wells. U.S. Filter/Johnson Screens, St. Paul, MN pp. 1089.

NTRPDC. 1993. Community Data, County of Tioga, Pennsylvania. Northern Tier Regional Planning and Development Commission. Towanda, Pennsylvania. 1993.

NOAA. 1999. Pennsylvania Climatologies Access Page at <http://www.cdc.noaa.gov/~cas/Climo/polys/pennsylvania.html>

Deutsch, W.J. 1997. Groundwater Geochemistry – Fundamentals and Applications to Contamination. Lewis Publishers.

U.S. EPA, 1989. Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual (Part A). Interim Final, Office of Emergency and Remedial Response, Washington, DC. EPA/540,1-89/002.

ATSDR, 1992. Toxicological Profile for Arsenic. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. February 18, 1992.

CCME, 1992. Canadian Water Quality Guidelines. Canadian Council of Ministers, Environmental Quality Guidelines Division. 1992 Update.

CCME, 1993. Canadian Water Quality Guidelines. Canadian Council of Ministers, Environmental Quality Guidelines Division. 1993 Update.



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- Eisler, R. 1986. Chromium Hazards To Fish, Wildlife, And Invertebrates: A Synoptic Review. Biological Report 85(1.6). Contaminant Hazard Reviews. January, 1986.
- Eisler, R. 1988. Arsenic Hazards To Fish, Wildlife, And Invertebrates: A Synoptic Review. Biological Report 85(1.12). Contaminant Hazard Reviews. January, 1988.
- Suter II, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota. ORNL Publication ES/ER/TM-96/R2.
- U.S. EPA. 1993. Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning. EPA-822-R-93-011.
- U.S. EPA. 1994. Equilibrium Partitioning Approach to Predicting Metal Bioavailability in Sediments and the Derivation of Sediment Quality Criteria for Metals. Prepared for EPA Science Advisory Board. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development. Volume I. EPA Report No. EPA-822-D-94-002. December 1994.
- U.S. EPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. June 1997.
- U.S. EPA. 1999. National Recommended Water Quality Criteria-Correction. United States Environmental Protection Agency, Office of Water. EPA 822-Z-99-001. April 1999.
- PaDEP 1997. Pennsylvania's Land Recycling Program Technical Guidance Manual, Final Draft. December 1997.